Evaluation of Montana's Lentic Breeding Amphibian Survey Methodology and Variables Correlated with Species Occupancy

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EXECUTIVE SUMMARY

Amphibian populations around the world and in Montana have undergone local and regional declines (Alford and Richards 2000; Houlahan et al. 2000; Maxell 2000; Maxell et al. 2003; Werner 2003; Werner et al. 2004). In light of these declines and a lack of baseline information on the distribution, status, habitat needs, and basic biology of Montana's amphibian and aquatic reptile species, (Maxell and Hokit 1999; Maxell 2000; Maxell et al. 2003), a multi-agency funded baseline inventory has been undertaken during the 1998-2005 field seasons (Figure 1) (Maxell 2004a-e, 2005).

Through the 2005 field season, 284 (62%) of the 459 randomly selected watersheds dominated by public land ownership have been initially surveyed. An additional 67 watersheds which were nonrandomly selected have been surveyed as requested by management agencies in order to address management issues such as land exchanges, fish stocking plans, and general wetland assessments (Figure 1) (Maxell 2005). Data from the 2005 field season is still being reviewed and compiled, but between the 1998 and 2004 field seasons, 5,473 surveys were conducted on 4,574 lentic wetlands across western and southeastern Montana. Of the 4,574 lentic sites surveyed during this time period, 250 sites in western Montana were surveyed between 2 and 22 times each. Of the 250 sites with multiple surveys, 44 sites had multiple surveys conducted each year over 1 to 3 years, making them suitable for evaluation of the variation in documentation of habitat covariates and estimation of true site occupancy rates in conjunction with local and landscape variables using recent theoretical and software advances.

In this report I: (1) evaluate levels of precision associated with the documentation of local, landscape, and species variables; (2) evaluate times to first detection of amphibian and gartersnake species; (3) estimate true site occupancy rates by accounting for imperfect detection of species in conjunction with local and landscape level habitat variables; and (4) make recommendations for collection and analysis of data in the future.

Most categorical and continuous variables that are currently being recorded as part of the Montana amphibian inventory program were associated with reasonably high levels of precision. Variables with lower levels of precision were usually associated with estimates of distances, percentages, or areas. Regularly pacing out distances as a check on visual estimates throughout the summer seems to provide the best means of ensuring consistency of estimates of distance and area across observers. Increasing levels of precision on estimates of percentages might be achieved through classroom estimates and discussions of site photos. Potentially some other sources of variation may be resulting from differing levels of effort between surveyors at sites that require more active search efforts (e.g., dipnetting in large wetlands with dense emergent vegetation). If true, this does raise the need to emphasize a consistent systematic approach toward dipnetting wetlands with large amounts of emergent vegetation.

Histograms of times at first detection for amphibians detected during field surveys (Figure 2) show that larvae and juveniles or adults are detected within the first 10 minutes of survey approximately 80 percent of the time and, if detected, are almost always detected within 40 to 50 minutes of searching. Amphibian eggs are detected within the first 10 minutes of survey 50 percent of the time for most species. Exceptions to this include egg strings of the western toad which may be cryptically wrapped around vegetation in larger wetlands and eggs of boreal chorus frogs which are very small and may easily be missed. However, eggs are almost always detected within 60 minutes of search. Gartersnakes are detected within the first 10 minutes approximately 55 percent of the time, with almost all detections occurring within 60 minutes. Sites where no species are detected are searched, on average, about the same amount of time as sites where species are detected, but this in no way ensures that species have been detected if present.

I used program PRESENCE (Version 2.0 <060127.1406>) to analyze matrices of detection histories and associated watershed and local site covariates, and sampling covariates. The relative support of data for candidate models was often increased by using relative abundance of a species life history stage as a covariate to the probability of detection. However, support of data for candidate models was not generally enhanced with by inclusion of date of survey, level of experience of surveyor, or area of emergent vegetation as a covariate to detection probability. It is clear from the relative support of data for models with some sort of anthropogenic impact over those with just the base covariates that some species are impacted by anthropogenic impacts we measured as part of our survey effort. Examples of this include fish as the apparent impact variable driving the high placement of impact variable models for long-toed salamander larvae, the high placement of overall impact models for western toad and Columbia spotted frog larvae, and the high placement of grazing impact models for western toad juveniles and adults and boreal chorus frog juveniles and adults. Other species do not seem to be affected by the anthropogenic impacts we measured while conducting surveys because their base variable models rank higher than or are equal to models with impact variables (e.g., tiger salamanders and terrestrial gartersnake juveniles and adults. With all of these model results it is important to keep in mind that it is always possible that a key explanatory variable may be missing from modeling efforts and that inclusion of this variable could upset our understanding of the relative importance of variables currently being considered.

Estimates of true site occupancy rates that correct for imperfect detection of species were much higher than naïve estimates resulting from the percentage of sites where species were detected (Table 7). These estimates of true occupancy rate were derived from the best fitting candidate models, thus supporting the contention that species often go undetected during our survey work. Most of these estimated true site occupancy rates make intuitive sense. For example, it seems entirely likely that Columbia spotted frog juveniles and adults occupy 93 percent of the water bodies within their known range while only being detected at 48 percent because they are highly vagile.

Recommendations for the amphibian inventory program include: (1) Regularly pacing out distances as a check on visual estimates; (2) hold two day spring training sessions using existing site photos and data sheets to expose field workers to a variety of issues in a common setting where everyone’s questions can be addressed; (3) pair new hires with returning personnel; (4) rotate field crew partners on a regular basis throughout the summer in order to ensure that the entire crew retains a collective standard approach; (5) restandardize everyone in the middle of the field season by having them all survey a set of sites to determine detection probabilities and compare responses; (6) work more closely with agency biologists on ways they can use the data.

INTRODUCTION

Amphibian populations around the world and in Montana have undergone local and regional declines (Alford and Richards 2000; Houlahan et al. 2000; Maxell 2000; Maxell et al. 2003; Werner 2003; Wake 2003; Werner et al. 2004). In light of these declines and a lack of baseline information on the distribution, status, habitat needs, and basic biology of Montana's amphibian and aquatic reptile species, (Maxell and Hokit 1999; Maxell 2000; Maxell et al. 2003), a multi-agency funded baseline inventory has been undertaken during the 1998-2005 field seasons (Figure 1) (Maxell 2004a-e, 2005). The primary response variables of interest for this project are the percent of watersheds and sites occupied by each species and the percent of watersheds and sites with breeding detected for each species. These response variables are valuable measures of the regional and local status of amphibian and aquatic reptile species that can be used for determining the management status of individual species. In addition to these variables, a number of local habitat variables (Appendices A & B) are recorded during surveys in order to: (1) establish a baseline of information on the status of lentic habitats; (2) highlight obvious management issues of concern so that management actions can be taken; and (3) determine whether any variables are correlated with species detections. Because these baseline surveys have been conducted at all standing water bodies on public lands in each watershed to this point in time, we can now begin to attempt to correlate patterns of detection/non-detection and relative abundance of amphibians and aquatic reptiles with some landscape level characteristics (e.g., number of breeding sites in a watershed, creation of breeding habitats by beaver, fish stocking, damming and diverting of waters, livestock grazing, roads, mining, and timber harvest) that either threaten populations or are necessary for their persistence.

Through the 2005 field season, 284 (62%) of the 459 randomly selected watersheds dominated by public land ownership have been initially surveyed and an additional 67 watersheds which were nonrandomly selected have been surveyed as requested by management agencies in order to address management issues such as land exchanges, fish stocking plans, and general wetland assessments (Figure 1A) (Maxell 2005). Data from the 2005 field season is still being reviewed and compiled, but between the 1998 and 2004 field seasons, 5,473 surveys were conducted on 4,574 lentic wetlands across western and southeastern Montana. Of the 4,574 lentic sites surveyed during this time period, 250 sites in western Montana were surveyed between 2 and 22 times each (Table 1; Figure 1B). Of the 250 sites with multiple surveys, 44 sites had multiple surveys conducted each year over 1 to 3 years (Table 1; Figure 1B). This history of multiple surveys allows the precision associated with documentation of habitat covariates to be determined. Furthermore, multiple surveys can be used in conjunction with recent theoretical advances and software applications (e.g., Mackenzie et al. 2002 and program PRESENCE) to allow for correction of naïve site occupancy rates by accounting for the fact that detection probability is less than one and varies by factors such has habitat, observer, and time of year. Furthermore, this correction for estimation of a species' true site occupancy rate can be combined with the analysis of local, landscape, and species covariates.

Given the numbers of surveys that have been conducted to date, and the desire of a number of management agencies to continue these efforts in order to assess both the status of species and the habitats on which they depend, there is a need to evaluate the methodology that has been used to date in order to identify potential improvements. In this report, I: (1) evaluate levels of precision associated with the documentation of local, landscape, and species variables; (2) evaluate times to first detection of amphibian and gartersnake species; (3) estimate true site occupancy rates by accounting for imperfect detection of species in conjunction with local and landscape level habitat variables; and (4) make recommendations for collection and analysis of data in the future

LEVELS OF PRECISION ASSOCIATED WITH DOCUMENTATION OF LOCAL, LANDSCAPE, AND SPECIES VARIABLES

Between 1998 and 2004, 250 sites in western Montana were surveyed between 2 and 22 times each (Table 1; Figure 1B) using the standardized data form and definitions provided in Appendix A. Of the 250 sites with multiple surveys, 44 had multiple surveys conducted each year over 1 to 3 years (Table 1; Figure 1B). This history of multiple surveys allows the precision associated with documentation of habitat covariates to be evaluated using coefficients of agreement for categorical variables and coefficients of variation for continuous variables (Portney and Watkins 1993). Coefficients of agreement (CA) are calculated as the number of exact agreements in a categorical response divided by the total number of responses. Values for CA range from 1 to 0 indicating complete agreement or a complete lack of agreement amongst responders, respectively, and can be thought of as ranging from 0 to 100 percent agreement in response. Coefficients of variation (CV) are calculated as the standard deviation (SD) divided by the mean (X) of a continuous response variable. Thus, a CV = 1 indicates the standard deviation of the responses to a particular continuous variable was equivalent in magnitude to the mean value of the responses to that variable. Because both CAs and CVs are standardized by dividing by the mean, in the case of CV, or total number, in the case of CA, categorical or continuous variables can readily be compared to other categorical or continuous variables, respectively, and ranked as to the level of precision associated with the variable.

Tables 2-4 summarize levels of precision associated with categorical and continuous variables defined on the standardized data form in Appendix A for sites highlighted in gray in Table 1. Variables within these tables are sorted so that variables with the highest levels of precision are at the tops of the tables and variables with the lowest levels of precision are at the bottoms of the tables.

Table 2 summarizes the degree of variation in responses of field personnel to habitat and species variables that should not vary between years. Because these variables are unlikely to vary between years all responses for these variables were pooled across all surveys and years. All of the categorical variables had high precision across responses with CA values ranging from 0.92 to 0.996, levels of precision that are unlikely to improve, but should be maintained. The level of precision associated with Distance to Forest was also fairly good (CV = 0.47) given that field estimates of distance tend to vary greatly between field crew members during the training period at the beginning of the field season. Regularly pacing out distances as a check on visual estimates throughout the summer seems to provide the best means of ensuring consistency of estimates of distance across observers.

Tables 3 and 4 summarize variation in responses to categorical and continuous variables that are likely to vary between years as a result of changes in weather, habitat, or species over time. Each of the variables summarized in these tables has three different measures associated with it depending on whether the measure of precision was calculated only from multiple surveys of the same site within a year (MSSWY), multiple surveys of the same site across years when multiple surveys were conducted each year (MSSAY), or from all surveys conducted at the site across all years (ASAY). These three levels of metrics were calculated in order to evaluate how precision of responses differed within a year versus between years. In general the MSSWY level metrics would be expected to have the highest level of precision since they were only calculated from surveys performed during the same year when habitats or species were most likely to be the same. For this reason, variables are sorted based on the precision of the MSSWY level of each variable in comparison to the MSSWY level of all other variables.

Most of the categorical variables in Table 3A had high levels of precision with responses agreeing 74 to 99 percent of the time. Those variables that were associated with lower levels of precision were typically associated with estimates of percentages or estimates of distance. Most of the continuous variables in Table 3B also had high levels of precision. It is not surprising that Fish Detection Time was variable because this would depend upon when each individual happened to first encounter fish. The fact that Area of Emergent vegetation had lower levels of precision is consistent with lower levels of precision being associated with variables involving estimates of distance. While several categorical variables associated with amphibian species in Table 4A had high levels of precision (CA > 0.9), a few only agreed an average of 60-70 percent of the time. I would speculate that this is a result of variation in detection of different numbers of animals between observers at sites with large amounts of emergent vegetation. Because animals are often hidden from the direct view of field personnel at sites with large amounts of emergent vegetation, it is more likely that different number classes would be reported as a result of different levels of dipnetting effort. If true, this does raise the need to emphasize a consistent systematic approach toward dipnetting wetlands with large amounts of emergent vegetation. Most of the continuous variables in Table 4B were fairly precise with SD less than the mean in virtually all cases. Variables with comparatively lower levels of precision were often associated with detection time which, for example, might depend on the direction a particular surveyor first approached the site. Other variables in Table 4B that were associated with comparatively lower levels of precision were species numbers which, as stated earlier, may vary as a result of level of effort in areas where more active searching is necessary such as wetlands with dense emergent vegetation.

TIME TO FIRST DETECTION FOR AMPHIBIAN AND GARTERSNAKE SPECIES

Histograms of times at first detection for amphibians detected during field surveys (Figure 2) show that larvae and juveniles or adults are detected within the first 10 minutes of survey approximately 80 percent of the time. This percentage and the general shape of the distribution of detection times remain remarkably consistent across most amphibian species for these life history stages. Larvae and juveniles or adults are almost always detected within 40 to 50 minutes of search time. Frequency distributions for times at first detection for eggs of these species are not as consistent, but eggs are detected within the first 10 minutes of survey 50 percent of the time for most species. Exceptions to this include egg strings of the western toad which may be cryptically wrapped around vegetation in larger wetlands and eggs of boreal chorus frogs which are very small and can be difficult to detect. Eggs are almost always detected within 60 minutes of search. Histograms of times at first detection for terrestrial and common gartersnakes are very similar with detection within the first 10 minutes approximately 55 percent of the time and with almost all detections occurring within 60 minutes of search.

The frequency distribution of total search times at sites where no species were detected (Figure 3A) is similar in shape to distributions of times at first detection. This may indicate that sites where no species are detected are searched, on average, about the same amount of time as sites where species are detected. However, this does not mean that all sites are searched long enough to detect species present in complex habitats that may conceal them (e.g., Figure 3B) and in no way ensures that species are detected if present.

EVALUATION OF SITE OCCUPANCY RATES IN CONJUNCTION WITH LOCAL AND LANDSCAPE LEVEL HABITAT VARIABLES

In order to account for the fact that detection probabilities for species are less than 1, sites can be surveyed on multiple occasions during the period of time species are likely to be present at a site, analogous to the closure assumption for closed mark-recapture models (Otis et al. 1978). These surveys can then be used to create a detection history which can be linked to site, watershed, and species covariates in order estimate a true rate of site occupancy as a function of these covariates (Mackenzie et al. 2002).

A large number of site, watershed, and sampling covariates (Table 5; Appendices A & B) were readily available for sites surveyed on one or more occasion between 2001 and 2004 within strata 4 and 6 of the statewide amphibian inventory sampling scheme (Figure 1, Maxell 2005). Using these available covariates, I built a small set of a priori candidate models for each species based on my knowledge of the natural history of the species as well as the need to systematically evaluate the potential impacts of grazing, damming of waters, introduction of fish, and harvest of timber on these species (Tables 6A-J). In general sets of candidate models included what I felt was a biologically meaningful “base” model, a model with all relevant “impact” variables, models which evaluated individual impact variables with the base model, and models which assessed the effect of numbers of animals, surveyor experience, day of year, and area of emergent vegetation on detectability. In a few instances additional models were constructed a posteriori to the analysis of some of the a priori candidate set in order to clearly understand the behavior of some of the covariates and ensure that the best fitting model was truly the best fitting model in the candidate set (e.g., ensuring that two covariates were not effectively canceling each other out and allowing the data to better fit another candidate model).

These models all assume that the detection process was independent at each site, that there was no unmodeled heterogeneity, and that sites were closed to changes in occupancy between sampling occasions (Mackenzie et al. 2002). Enough data was available to construct candidate models for long-toed salamander (*Ambystoma macrodactylum*) larvae, tiger salamander (*Ambystoma tigrinum*) larvae, western toad (*Bufo boreas*) larvae and juveniles or adults, boreal chorus frogs (*Pseudacris maculata*) larvae and juveniles or adults, Columbia spotted frog (*Rana luteiventris*) larvae and juveniles or adults, terrestrial gartersnake (*Thamnophis elegans*) juveniles or adults, and common gartersnake (*Thamnophis sirtalis*) juveniles or adults. Maxell (2000), Maxell et al. (2003), and Werner et al. (2004) contain literature reviews and other sources of information on the biology of these species which can be used to assess the biological relevance of these candidate models.

I used program PRESENCE (Version 2.0 <060127.1406>) to analyze matrices of detection histories and associated watershed and local site covariates, and sampling covariates. PRESENCE assesses the relative fit of the *a priori* candidate models to the data gathered using Akaike Information Criteria (AIC) which takes a parsimonious approach toward balancing the risk of overfitting models to data so that they are not applicable beyond the dataset being analyzed by penalizing candidate models for each additional parameter that is estimated (Burnam and Anderson 2002). Models that are within a few AIC values of one another indicate that there is essentially equal fit of the data to all models and the AIC weights indicate the relative support of the data for the model relative to the support of the data for all other models (Burnham and Anderson 2002). Candidate models in Tables 6A-J are sorted so that the best fitting candidate model is at the top of each page.

The relative support of the data for candidate models in Tables 6A-J clearly shows that the probability of detection (ρ) of a given life history stage of a species is dependent on the relative abundance of that life history stage. This is evident from the fact that when the relative abundance of a species is included in the model the data fit the model better than when the model lacked this covariate for probability of detection (e.g., long-toed salamander larvae in Table 6A, tiger salamander larvae in Table 6B, and boreal chorus frog larvae and juveniles or adults in Tables 6E&F). On the other hand there was little evidence to support any contention that date of survey, level of experience of the surveyor, or area of emergent vegetation was critical to ρ since models focusing on these variables as covariates to ρ were never really in the higher ranked candidate models.

It is also clear from the relative support of data for models with some sort of anthropogenic impact over those with just the base covariates that some species are impacted by covariates we measured while surveying sites. Examples of this include fish as the apparent impact variable driving the high placement of impact variable models for long-toed salamander larvae in Table 6A, the high placement of overall impact models for western toad and Columbia spotted frog larvae in Tables 6C and 6G, respectively, and the high placement of grazing impact models for western toad juveniles and adults (Table 6D) and boreal chorus frog juveniles and adults (Table

6F). Other species do not seem to be affected by the anthropogenic impacts we measured while conducting surveys because their base variable models rank higher than or are equal to models with impact variables included (e.g., tiger salamanders in Table 6B and terrestrial gartersnake juveniles and adults in Table 6L). Finally, model results are not clear regarding the importance of impacts to Columbia spotted frog juveniles and adults in Table 6H or common gartersnakes in Table 6J because several of the top models have roughly equal weighting. With all of these model results it is important to keep in mind one of the central assumptions of modeling in PRESENCE, namely that there is assumed to be no unmodeled heterogeneity. Clearly this assumption is likely to be violated given the relatively limited pool of covariates (e.g., no major GIS layers were included in the landscape variables due to lack of time and resources to consider these variables) and because this dataset is relatively unexplored. The bottom line is that it is always possible that a key explanatory variable may be missing from modeling efforts and that inclusion of this variable could upset our understanding of the relative importance of variables currently being considered.

Estimates of true site occupancy rates that correct for imperfect detection of species were much higher than naïve estimates resulting from the percentage of sites where species were detected (Table 7). These estimates of true occupancy rate were derived from the best fitting candidate models, thus supporting the contention that species often go undetected during our survey work. Most of these estimated true site occupancy rates make intuitive sense. For example, it seems entirely likely that Columbia spotted frog juveniles and adults occupy 93 percent of the water bodies within their known range while only being detected at 48 percent because they are highly vagile. No estimates were able to be calculated for western toads because they are encountered so infrequently that their data set could not support parameter estimation.

RECOMMENDATIONS FOR FUTURE

Most categorical and continuous variables that are currently being recorded as part of the Montana amphibian inventory program were associated with reasonably high levels of precision and do not appear to currently represent a threat to our ability to detect changes in these variables over time. In part this may be a result of the extensive review process all data is currently subjected to, with each site photo and map reviewed against the data for discrepancies as well as internal inconsistencies. However, there is always room for improvement. Variables with lower levels of precision were usually associated with estimates of distances, percentages, or areas. Regularly pacing out distances as a check on visual estimates throughout the summer seems to provide the best means of ensuring consistency of estimates of distance and area across observers. Increasing levels of precision on estimates of percentages might be achieved through classroom estimates and discussions of site photos. In fact, a two day training session using existing site photos and data sheets would be a wonderful way of ensuring that all field crew members (volunteer or not) were exposed to a variety of situations while in the presence of supervisors that could give them feedback as a group. Other ideas for ensuring consistency of responses across field personnel across the entire field season include: (1) providing a great deal of feedback to new hires or volunteers during the first few weeks they work on the project by pairing them with a returning person; (2) rotating field crew partners on a regular basis throughout the summer in order to ensure that the entire crew retains a collective standard approach; and (3) restandardize everyone in the middle of the field season by having them all survey a set of sites to determine detection probabilities and compare responses.

Potentially some other sources of variation may be resulting from differing levels of effort between surveyors at sites that require more active search efforts (e.g., dipnetting in large wetlands with dense emergent vegetation). If true, this does raise the need to emphasize a consistent systematic approach toward dipnetting wetlands with large amounts of emergent vegetation.

At a programmatic level the statewide amphibian inventory project has three years of fieldwork remaining before it has a baseline status assessment for watersheds across the state that are dominated by public lands (Maxell 2005). It is now time to begin planning surveys on private and tribal land ownership strata which have not been addressed to date. Finally, we need to work more closely with agency biologists so that they are aware of the amphibian inventory data set and how it might allow them to better manage amphibians and the wetland habitats they depend on.

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Table 1

Summary of numbers of site surveys conducted each year between 1998 and 2004 for lentic sites surveyed more than once during this time period. Shaded Site IDs indicate sites with multiple surveys during at least one year which makes them suitable for assessment of variation in site evaluations and calculation of detection probabilities (Mean and SD = average and standard deviation of number of surveys for each site across years).

	Number of Surveys For Each Lentic Site By Year									
Site ID	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**Total**	**Mean**	**SD**
1013006				1			1	2	1.0	0.0
3003002				2	3	4		9	3.0	1.0
3008001			1	1	1			3	1.0	0.0
3008002			1	1	1			3	1.0	0.0
3008003			1	1				2	1.0	0.0
3008004				1	1			2	1.0	0.0
3008005				1	1			2	1.0	0.0
3008006				1	1			2	1.0	0.0
3008007				1	1			2	1.0	0.0
3008008				1	1			2	1.0	0.0
3008009				1	1			2	1.0	0.0
4001001			1			1		2	1.0	0.0
4001002				1		1	1	3	1.0	0.0
4027006			1	1	1	1	1	5	1.0	0.0
4027007			1		1	1	1	4	1.0	0.0
4027024				1		1	1	3	1.0	0.0
4027025				1	1	1	1	4	1.0	0.0
4034001				1	1		1	3	1.0	0.0
4038001			1	1				2	1.0	0.0
4044001			1	1	1	6	9	18	3.6	3.7
4044002			1	1	4	4	8	18	3.6	2.9
4044003			1	1	6	3	9	20	4.0	3.5
4044004			1	1	4	6	8	20	4.0	3.1
4044099			1	1	6	6	8	22	4.4	3.2
4044100				2	6	6	8	22	5.5	2.5
4044101						4	8	12	6.0	2.8
4044102						4	8	12	6.0	2.8
4049023					1		1	2	1.0	0.0
4056001			1		1			2	1.0	0.0
4056002			1		1			2	1.0	0.0
4056003			1		1			2	1.0	0.0
4056004			1		1			2	1.0	0.0
4056005			1		1			2	1.0	0.0
4056006			1		1			2	1.0	0.0
4056007			1		1			2	1.0	0.0
4056008			1		1			2	1.0	0.0
4056009			1		1			2	1.0	0.0
4056010			1		1			2	1.0	0.0
4056011			1		1			2	1.0	0.0
4056012			1		1			2	1.0	0.0
4056013			1		1			2	1.0	0.0
4056014			1		1			2	1.0	0.0
4056015			1		1			2	1.0	0.0
4056016			1		1			2	1.0	0.0
4056017			1		1			2	1.0	0.0
4056018			1		1			2	1.0	0.0

Table 1 Continued

SITE_ID	1998	1999	2000	2001	2002	2003	2004	Total	Mean	SD
4056019			1		1			2	1.0	0.0
4056020			1		1			2	1.0	0.0
4056021			1		1			2	1.0	0.0
4056022			1		1			2	1.0	0.0
4056023			1		1			2	1.0	0.0
4056024			1		1			2	1.0	0.0
4056026			1		1			2	1.0	0.0
4057011						1	1	2	1.0	0.0
4057020						1	1	2	1.0	0.0
4058001			1	1	6	1		9	2.3	2.5
4058002			1	1	6	1		9	2.3	2.5
4058003			1	1	6	1		9	2.3	2.5
4058004			1	1	6	1		9	2.3	2.5
4058005			1	1	6	1		9	2.3	2.5
4058006			1	1	6	1		9	2.3	2.5
4058007			1	1	6	1		9	2.3	2.5
4058008			1	1	6	1		9	2.3	2.5
4058009			1	1	6	1		9	2.3	2.5
4058010			1	1	6	1		9	2.3	2.5
4058011			1	1	6	1		9	2.3	2.5
4058012			1	1	6	1		9	2.3	2.5
4058013			1	1	6	1		9	2.3	2.5
4058014			1	1	6	1		9	2.3	2.5
4058015			1	1	6	1		9	2.3	2.5
4058066			1	1	1	1		4	1.0	0.0
4058067			1	1	1	1		4	1.0	0.0
4058068			1	1	1	1		4	1.0	0.0
4058069			1	1	1	1		4	1.0	0.0
4058070			1	1	1	1		4	1.0	0.0
4058071			1	1	1	1		4	1.0	0.0
4058072			1	1	1	1		4	1.0	0.0
4058073				1	1	1		3	1.0	0.0
4058074				1	1	1		3	1.0	0.0
4058075				1	1	1		3	1.0	0.0
4058076				1	1	1		3	1.0	0.0
4058077			1	1	1	1		4	1.0	0.0
4058078			1	1	1	1		4	1.0	0.0
4058079			1	1	1	1		4	1.0	0.0
4058080				1	1	1		3	1.0	0.0
4058081			1	1	1	1		4	1.0	0.0
4058082			1	1	1	1		4	1.0	0.0
4058083			1	1	1	1		4	1.0	0.0
4058084			1	1	1	1		4	1.0	0.0
4060006						1	1	2	1.0	0.0
4060009						1	1	2	1.0	0.0
4063001			1	2	2			5	1.7	0.6
4064090				1	1		1	3	1.0	0.0
4072006				1	1			2	1.0	0.0
4078001						1	1	2	1.0	0.0
4993001			1	1	1		7	10	2.5	3.0
4995001			1	1	1	1		4	1.0	0.0
4995002			1	1	1	1		4	1.0	0.0

Table 1 Continued

SITE_ID	1998	1999	2000	2001	2002	2003	2004	Total	Mean	SD
4995003			1	1	1	1		4	1.0	0.0
4995004			1	1	1	1		4	1.0	0.0
4995005			1	1	1	1		4	1.0	0.0
4995006			1	1	1	1		4	1.0	0.0
4995007			1	1	1	1		4	1.0	0.0
4995008			1	1	1	1		4	1.0	0.0
4995009			1	1	1	1		4	1.0	0.0
4995010			1	1	1	1		4	1.0	0.0
4995011			1	1	1	1		4	1.0	0.0
4995012				1	1	1		3	1.0	0.0
4995013			1	1	1	1		4	1.0	0.0
4995014			1	1	1	1		4	1.0	0.0
4995015			1	1	1	1		4	1.0	0.0
4995016			1	1	1	1		4	1.0	0.0
4995017			1	1	1	1		4	1.0	0.0
4995018			1	1	1	1		4	1.0	0.0
4995019			1	1	1	1		4	1.0	0.0
4995020			1	1	1	1		4	1.0	0.0
4995021			1	1	1	1		4	1.0	0.0
5006001				1		1	1	3	1.0	0.0
5012002						1	1	2	1.0	0.0
5014001			1	1	1	1	1	5	1.0	0.0
5014002				1	1	1		3	1.0	0.0
5014003				1	1	1		3	1.0	0.0
5014004				1	1			2	1.0	0.0
5014005				1	1			2	1.0	0.0
5014006				1	1			2	1.0	0.0
5014010				1	1			2	1.0	0.0
5014011				1	1			2	1.0	0.0
5014012				1	1			2	1.0	0.0
5014013				1	1			2	1.0	0.0
5014014				1	1			2	1.0	0.0
5014015				1	1			2	1.0	0.0
5014016				1	1			2	1.0	0.0
5014017				1	1			2	1.0	0.0
5014018				1	1			2	1.0	0.0
5014019				1	1			2	1.0	0.0
5014020				1	1			2	1.0	0.0
5014021				1	1			2	1.0	0.0
5014022				1	1	1		3	1.0	0.0
5014023				1	1	1		3	1.0	0.0
5014024				1	1	1		3	1.0	0.0
5014025				1	1	1		3	1.0	0.0
5014026				1	1	1		3	1.0	0.0
5014027				1	1	1		3	1.0	0.0
5014028				1	1	1		3	1.0	0.0
5014029				1	1	1		3	1.0	0.0
5014030				1	1			2	1.0	0.0
5017001					1	1		2	1.0	0.0

Table 1 Continued

SITE_ID	1998	1999	2000	2001	2002	2003	2004	Total	Mean	SD
5017002					1	1		2	1.0	0.0
5026001				1	1			2	1.0	0.0
5026002				1	1			2	1.0	0.0
5026003				1	1			2	1.0	0.0
5026004				1	1			2	1.0	0.0
5026005				1	1			2	1.0	0.0
5999001	1				1	1		3	1.0	0.0
5999008	1						1	2	1.0	0.0
5999010	1				1	1	1	4	1.0	0.0
5999011	1					1		2	1.0	0.0
5999013		1			1	1		3	1.0	0.0
6002008						1	1	2	1.0	0.0
6015009						1	1	2	1.0	0.0
6015010						1	1	2	1.0	0.0
6021011					2			2	2.0	-
6024010						1	1	2	1.0	0.0
6025001					6	6	8	20	6.7	1.2
6025002				1	1	6	8	16	4.0	3.6
6025003				1	5	6	9	21	5.3	3.3
6025004				1	6	6	8	21	5.3	3.0
6025005				1	5	6	8	20	5.0	2.9
6025006				1	1	6	8	16	4.0	3.6
6025007				1	6	6	8	21	5.3	3.0
6025008				1	1	6	8	16	4.0	3.6
6025009				1	1		8	10	3.3	4.0
6025010				1	1			2	1.0	0.0
6025011				1	6	6	8	21	5.3	3.0
6025096							4	4	4.0	-
6025097							4	4	4.0	-
6025098							7	7	7.0	-
6025099					5	6	8	19	6.3	1.5
6025100				1	1	6	8	16	4.0	3.6
6025108						6	8	14	7.0	1.4
6025109					6	6	8	20	6.7	1.2
6025110					6	6	8	20	6.7	1.2
6028073						1	1	2	1.0	0.0
6043001						1	1	2	1.0	0.0
6043002						1	1	2	1.0	0.0
6046007				1			1	2	1.0	0.0
6046016				1			1	2	1.0	0.0
6046017				1			1	2	1.0	0.0
6046020				1			1	2	1.0	0.0
6046021				1			1	2	1.0	0.0
6046099						1	1	2	1.0	0.0
6047001						1	1	2	1.0	0.0
6047005						1	1	2	1.0	0.0
6049001					2			2	2.0	-
6049021					3			3	3.0	-
6049022					2			2	2.0	-
6049023					2			2	2.0	-
6052002						1	1	2	1.0	0.0
6057007						1	1	2	1.0	0.0

Table 1 Continued

SITE_ID	1998	1999	2000	2001	2002	2003	2004	Total	Mean	SD
8001001			1		1			2	1.0	0.0
8001002			1		1			2	1.0	0.0
8001003			1		1			2	1.0	0.0
9004001			1		1			2	1.0	0.0
12014015					1		1	2	1.0	0.0
15301001				1	1			2	1.0	0.0
15301002				1	1	2	1	5	1.3	0.5
15303001				1	2	2		5	1.7	0.6
15304001				2	1	2		5	1.7	0.6
15305004					1	1		2	1.0	0.0
15400002				2	1	1	1	5	1.3	0.5
15400006						1	1	2	1.0	0.0
15407001		1		1	1	1	1	5	1.0	0.0
15407002		1		1	1	1	1	5	1.0	0.0
15407003		1				1	1	3	1.0	0.0
15407004				1		1	1	3	1.0	0.0
15408003				1	1			2	1.0	0.0
15410001				1	1	1	1	4	1.0	0.0
15413001				1	1	1	1	4	1.0	0.0
15414001					1		1	2	1.0	0.0
15414002					1		1	2	1.0	0.0
15418001				1			1	2	1.0	0.0
15419001				1	1	1	1	4	1.0	0.0
15420001				1	1	1	1	4	1.0	0.0
15424001					1	1		2	1.0	0.0
15428001						1	1	2	1.0	0.0
15428002						1	1	2	1.0	0.0
15428003						1	1	2	1.0	0.0
15504001				1		1		2	1.0	0.0
15505001				1		1		2	1.0	0.0
15506001				1	1	1	1	4	1.0	0.0
15509001					1	1	1	3	1.0	0.0
15510001					1	1	1	3	1.0	0.0
15510002					1	2		3	1.5	0.7
15510003					1	1		2	1.0	0.0
15510004					1	1		2	1.0	0.0
15510005					1	1		2	1.0	0.0
15607002					1	1	1	3	1.0	0.0
15609001					1		1	2	1.0	0.0
15609005					1		1	2	1.0	0.0
15611001				1	1	1		3	1.0	0.0
15612001						1	1	2	1.0	0.0
15612002					1	1	1	3	1.0	0.0
15612004					1	1	1	3	1.0	0.0
15612005					1	1		2	1.0	0.0
15613001					1	1	1	3	1.0	0.0
15613002					1	1	1	3	1.0	0.0
15613003						1	1	2	1.0	0.0
15613004					1	1	1	3	1.0	0.0
15613005					1	1		2	1.0	0.0
15621001				1		1		2	1.0	0.0
Totals	**4**	**4**	**93**	**155**	**348**	**267**	**277**	**1148**	**164**	**137.6**

Table 2

Levels of precision associated with documentation of habitat and species variables that should not vary between years using coefficients of agreement (CA) and coefficients of variation (CV) to assess variation in responses to categorical and continuous variables, respectively.

Habitat Variable[1]	Method of Evaluation[2]	N[3]	X[4]	SD[4]	Min[4]	Max[4]
Mining Activity	CA	233	0.996	0.04	0.5	1
Water Dammed	CA	234	0.99	0.05	0.5	1
Support Reproduction	CA	249	0.99	0.06	0.5	1
Shallows Present on N	CA	229	0.98	0.07	0.5	1
Site Origin	CA	249	0.97	0.1	0.36	1
Timber Harvest	CA	245	0.97	0.1	0.5	1
Primary Substrate	CA	237	0.97	0.11	0.33	1
Fish Detected	CA	232	0.97	0.12	0.5	1
Water Permanence	CA	247	0.96	0.11	0.5	1
Habitat Type	CA	249	0.96	0.12	0.5	1
Fish Spawning Habitat	CA	191	0.96	0.12	0.5	1
Water Connectedness	CA	244	0.95	0.13	0.43	1
Emergent Veg Present N	CA	228	0.95	0.13	0.5	1
Inlet Substrate	CA	56	0.93	0.15	0.5	1
Outlet Substrate	CA	52	0.92	0.18	0.4	1
Fish Species	CA	To many unidentified trout for evaluation				
Distance to Forest	CV	238	0.47	0.53	0	2.3

[1] Variables are sorted first by method of evaluation and then in descending order from those with higher levels of precision to those with lower levels of precision.

[2] CA values of 1 and 0 indicate complete agreement and a complete lack of agreement, respectively, of values recorded for the variable across all surveys. CV values simply represent the standard deviation divided by the mean. Thus, a CV = 1 indicates the standard deviation of the responses was equivalent in magnitude to the mean value of the responses.

[3] N indicates numbers of sites for which CA or CV could be calculated because of multiple surveys evaluating the variable.

[4] X, SD, Min, and Max are the overall mean, standard deviation, minimum, and maximum values for CA and CV values calculated for sites with multiple surveys where the variable was documented.

Table 3A

Levels of precision associated with documentation of habitat variables that are likely to vary between years using coefficients of agreement (CA) to assess variation in responses to categorical variables.

Habitat Variable[1]	Method of Evaluation[2]	N[3]	X[4]	SD[4]	Min[4]	Max[4]
Site Dry - MSSWY	CA	80	0.99	0.05	0.67	1
Site Dry - MSSAY	CA	44	0.94	0.12	0.5	1
Site Dry - ASAY	CA	249	0.98	0.09	0.5	1
Grazing Impact – MSSWY	CA	80	0.94	0.15	0.38	1
Grazing Impact – MSSAY	CA	44	0.88	0.18	0.42	1
Grazing Impact - ASAY	CA	233	0.94	0.15	0.42	1
Water Turbidity - MSSWY	CA	76	0.93	0.12	0.63	1
Water Turbidity - MSSAY	CA	43	0.9	0.15	0.5	1
Water Turbidity - ASAY	CA	228	0.94	0.15	0.5	1
Maximum Depth - MSSWY	CA	75	0.87	0.16	0.33	1
Maximum Depth - MSSAY	CA	42	0.86	0.18	0.5	1
Maximum Depth - ASAY	CA	231	0.91	0.17	0.33	1
Water Color - MSSWY	CA	75	0.87	0.15	0.5	1
Water Color - MSSAY	CA	43	0.87	0.16	0.5	1
Water Color - ASAY	CA	228	0.93	0.15	0.5	1
Dominant Emergent Veg - MSSWY	CA	74	0.81	0.2	0.33	1
Dominant Emergent Veg - MSSAY	CA	42	0.83	0.18	0.38	1
Dominant Emergent Veg - ASAY	CA	204	0.91	0.17	0.25	1
Percent Larval Activity - MSSWY	CA	75	0.78	0.21	0.25	1
Percent Larval Activity - MSSAY	CA	42	0.73	0.21	0.25	1
Percent Larval Activity - ASAY	CA	202	0.79	0.23	0.25	1
Percent Emergent Veg - MSSWY	CA	73	0.75	0.2	0.33	1
Percent Emergent Veg – MSSAY	CA	42	0.73	0.21	0.35	1
Percent Emergent Veg – ASAY	CA	230	0.85	0.22	0.33	1
Percent < 50 cm - MSSWY	CA	75	0.74	0.23	0.33	1
Percent < 50 cm - MSSAY	CA	43	0.74	0.24	0.3	1
Percent < 50 cm - ASAY	CA	226	0.86	0.21	0.3	1

1 Variables are sorted in descending order from those with higher of levels of precision to those with lower levels of precision on the MSSWY method of calculation. MSSWY indicates values were calculated only from multiple surveys of a site conducted within a single year. MSSAY indicates values were calculated from all surveys at sites with multiple surveys conducted within at least one of the years of sampling (corresponds to shaded Site IDs in Table 1). ASAY indicates values were calculated from all surveys conducted across all years (i.e. sites were surveyed multiple times either within years, between years, or both corresponding to all Site IDs listed in Table 1).

2 CA values of 1 and 0 indicate complete agreement and a complete lack of agreement, respectively, of values recorded for the variable across all surveys.

3 N indicates numbers of sites for which CA could be calculated because of multiple surveys evaluating the variable.

4 X, SD, Min, and Max are the overall mean, standard deviation, minimum, and maximum values for CA values calculated for sites with multiple surveys where the variable was documented.

Table 3B

Levels of precision associated with documentation of habitat variables that are likely to vary between years using coefficients of variation (CV) to assess variation in responses to continuous variables.

Habitat Variable[1]	Method of Evaluation[2]	N[3]	X[4]	SD[4]	Min[4]	Max[4]
Water pH – MSSWY	CV	106	0.05	0.03	0	0.13
Water pH – MSSAY	CV	26	0.06	0.04	0	0.16
Water pH – ASAY	CV	136	0.07	0.08	0	0.4
Inlet Width - MSSWY	CV	25	0.37	0.23	0	0.87
Inlet Width - MSSAY	CV	15	0.38	0.25	0	0.82
Inlet Width - ASAY	CV	56	0.29	0.28	0	1.05
Outlet Width - MSSWY	CV	25	0.4	0.28	0	1.11
Outlet Width - MSSAY	CV	15	0.44	0.21	0.13	0.81
Outlet Width - ASAY	CV	53	0.27	0.3	0	1.18
Inlet Depth - MSSWY	CV	26	0.54	0.36	0.12	1.86
Inlet Depth - MSSAY	CV	14	0.51	0.21	0.12	0.84
Inlet Depth - ASAY	CV	56	0.4	0.39	0	1.4
Outlet Depth – MSSWY	CV	36	0.57	0.33	0	1.86
Outlet Depth – MSSAY	CV	15	0.56	0.22	0.24	1.02
Outlet Depth – ASAY	CV	52	0.41	0.35	0	1.16
Emergent Vegetation Area - MSSWY	CV	73	0.84	0.44	0.13	2.15
Emergent Vegetation Area - MSSAY	CV	42	0.94	0.6	0.13	2.89
Emergent Vegetation Area - ASAY	CV	213	0.45	0.54	0	2.89
Fish Detection Time - MSSWY	CV	4	0.89	0.45	0.3	1.38
Fish Detection Time - MSSAY	CV	3	1.09	0.28	0.89	1.41
Fish Detection Time - ASAY	CV	24	0.73	0.43	0	1.41

[1] Variables are sorted in descending order from those with higher of levels of precision to those with lower levels of precision on the MSSWY method of calculation. MSSWY indicates values were calculated only from multiple surveys of a site conducted within a single year. MSSAY indicates values were calculated from all surveys at sites with multiple surveys conducted within at least one of the years of sampling (corresponds to shaded Site IDs in Table 1). ASAY indicates values were calculated from all surveys conducted across all years (i.e. sites were surveyed multiple times either within years, between years, or both corresponding to all Site IDs listed in Table 1).

[2] CV values simply represent the standard deviation divided by the mean. Thus, a CV = 1 indicates the standard deviation of the responses was equivalent in magnitude to the mean value of the responses.

[3] N indicates numbers of sites for which CV could be calculated because of multiple surveys evaluating the variable.

[4] X, SD, Min, and Max are the overall mean, standard deviation, minimum, and maximum values for CV values calculated for sites with multiple surveys where the variable was documented.

Table 4A

Levels of precision associated with documentation of species variables that are likely to vary between years using coefficients of agreement (CA) to assess variation in responses to categorical variables.

Species Variable[1]	Method of Evaluation[2]	N[3]	X[4]	SD[4]	Min[4]	Max[4]
RALU Cover from Fish - MSSWY	CA	2	1	-	1	1
RALU Cover from Fish - MSSAY	CA	2	1	-	1	1
RALU Cover from Fish - ASAY	CA	13	0.96	0.14	0.5	1
PSMA Breeding with Fish - MSSWY	CA	22	1	0	1	1
PSMA Breeding with Fish - MSSAY	CA	12	1	0	1	1
PSMA Breeding with Fish - ASAY	CA	16	0.97	0.13	0.5	1
RALU Breeding with Fish - MSSWY	CA	63	0.99	0.05	0.63	1
RALU Breeding with Fish - MSSAY	CA	36	0.99	0.04	0.75	1
RALU Breeding with Fish - ASAY	CA	133	0.95	0.13	0.5	1
AMTI Breeding with Fish - MSSWY	CA	19	0.98	0.08	0.67	1
AMTI Breeding with Fish - MSSAY	CA	11	0.98	0.08	0.75	1
AMTI Breeding with Fish - ASAY	CA	12	0.94	0.16	0.5	1
BUBO Breeding with Fish - MSSWY	CA	8	0.94	0.18	0.5	1
BUBO Breeding with Fish - MSSAY	CA	4	0.88	0.25	0.5	1
BUBO Breeding with Fish - ASAY	CA	48	0.94	0.15	0.5	1
AMMA Breeding with Fish - MSSWY	CA	8	0.94	0.18	0.5	1
AMMA Breeding with Fish - MSSAY	CA	10	0.97	0.11	0.67	1
AMMA Breeding with Fish - ASAY	CA	41	0.98	0.09	0.5	1
RALU Larvae Number Class - MSSWY	CA	38	0.71	0.18	0.33	1
RALU Larvae Number Class - MSSAY	CA	22	0.64	0.2	0.33	1
RALU Larvae Number Class - ASAY	CA	51	0.55	0.18	0.25	1
AMMA Larvae Number Class - MSSWY	CA	8	0.7	0.16	0.5	1
AMMA Larvae Number Class - MSSAY	CA	10	0.69	0.28	0.33	1
AMMA Larvae Number Class - ASAY	CA	35	0.78	0.24	0.33	1
BUBO Larvae Number Class - MSSWY	CA	5	0.69	0.21	0.5	1
BUBO Larvae Number Class - MSSAY	CA	3	0.53	0.13	0.41	0.67
BUBO Larvae Number Class - ASAY	CA	25	0.65	0.22	0.33	1
AMTI Larvae Number Class - MSSWY	CA	11	0.69	0.2	0.33	1
AMTI Larvae Number Class - MSSAY	CA	6	0.56	0.13	0.38	0.71
AMTI Larvae Number Class - ASAY	CA	7	0.55	0.12	0.38	0.71
PSMA Larvae Number Class - MSSWY	CA	19	0.59	0.21	0.25	1
PSMA Larvae Number Class - MSSAY	CA	12	0.52	0.12	0.33	0.67
PSMA Larvae Number Class - ASAY	CA	15	0.55	0.17	0.33	1

Table 4A Continued

Species Variable[1]	Method of Evaluation[2]	N[3]	X[4]	SD[4]	Min[4]	Max[4]
AMMA Cover from Fish - MSSWY	CA	0	-	-	-	-
AMMA Cover from Fish - MSSAY	CA	2	1	0	1	1
AMMA Cover from Fish - ASAY	CA	5	1	0	1	1
AMTI Cover from Fish - MSSWY	CA	0	-	-	-	-
AMTI Cover from Fish - MSSAY	CA	0	-	-	-	-
AMTI Cover from Fish - ASAY	CA	0	-	-	-	-
BUBO Cover from Fish - MSSWY	CA	0	-	-	-	-
BUBO Cover from Fish - MSSAY	CA	1	1	-	1	1
BUBO Cover from Fish - ASAY	CA	11	0.95	0.1	0.75	1
PSMA Cover from Fish - MSSWY	CA	0	-	-	-	-
PSMA Cover from Fish - MSSAY	CA	0	-	-	-	-
PSMA Cover from Fish - ASAY	CA	0	-	-	-	-

[1] Variables are sorted in descending order from those with higher of levels of precision to those with lower levels of precision on the MSSWY method of calculation. MSSWY indicates values were calculated only from multiple surveys of a site conducted within a single year. MSSAY indicates values were calculated from all surveys at sites with multiple surveys conducted within at least one of the years of sampling (corresponds to shaded Site IDs in Table 1). ASAY indicates values were calculated from all surveys conducted across all years (i.e. sites were surveyed multiple times either within years, between years, or both corresponding to all Site IDs listed in Table 1). AMMA = Long-toed Salamander (*Ambystoma macrodactylum*), AMTI = Tiger Salamander (*Ambystoma tigrinum),* BUBO = Western Toad (*Bufo boreas*), PSMA = Boreal Chorus Frog (*Pseudacris maculata*), RALU = Columbia Spotted Frog (*Rana luteiventris*), Terrestrial Gartersnake (*Thamnophis elegans*), THSI = Common Gartersnake (*Thamnophis sirtalis*).

[2] CA values of 1 and 0 indicate complete agreement and a complete lack of agreement, respectively, of values recorded for the variable across all surveys.

[3] N indicates numbers of sites for which CA could be calculated because of multiple surveys evaluating the variable.

[4] X, SD, Min, and Max are the overall mean, standard deviation, minimum, and maximum values for CA values calculated for sites with multiple surveys where the variable was documented.

Table 4B

Levels of precision associated with documentation of species variables that are likely to vary between years using coefficients of variation (CV) to assess variation in responses to continuous variables.

Species Variable[1]	Method of Evaluation[2]	N[3]	X[4]	SD[4]	Min[4]	Max[4]
AMTI J & A Detection Time - MSSWY	CV	1	0.18	-	0.18	0.18
AMTI J & A Detection Time - MSSAY	CV	2	0.09	0.13	0	0.18
AMTI J & A Detection Time - ASAY	CV	2	0.09	0.13	0	0.18
PSMA J & A Detection Time - MSSWY	CV	2	0.34	0.23	0.18	0.5
PSMA J & A Detection Time - MSSAY	CV	2	0.34	0.23	0.18	0.5
PSMA J & A Detection Time - ASAY	CV	2	0.34	0.23	0.18	0.5
THEL Juv & Adult Numbers - MSSWY	CV	24	0.34	0.25	0	0.75
THEL Juv & Adult Numbers - MSSAY	CV	23	0.3	0.25	0	0.74
THEL Juv & Adult Numbers - ASAY	CV	32	0.26	0.25	0	0.74
THSI Juv & Adult Numbers - MSSWY	CV	11	0.4	0.36	0	1.01
THSI Juv & Adult Numbers - MSSAY	CV	19	0.22	0.25	0	0.84
THSI Juv & Adult Numbers - ASAY	CV	27	0.23	0.31	0	1.1
THSI J&A Detection Time - MSSWY	CV	1	0.47	-	0.47	0.47
THSI J&A Detection Time - MSSAY	CV	1	0.47	-	0.47	0.47
THSI J&A Detection Time - ASAY	CV	1	0.47	-	0.47	0.47
THEL J&A Detection Time - MSSWY	CV	6	0.53	0.3	0.18	1.1
THEL J&A Detection Time - MSSAY	CV	5	0.62	0.16	0.47	0.81
THEL J&A Detection Time - ASAY	CV	5	0.62	0.16	0.47	0.81
AMTI Juv & Adult Numbers - MSSWY	CV	16	0.55	0.3	0	1.16
AMTI Juv & Adult Numbers - MSSAY	CV	11	0.65	0.32	0	1.16
AMTI Juv & Adult Numbers - ASAY	CV	11	0.65	0.32	0	1.16
BUBO Egg Numbers - MSSWY	CV	1	0.56	-	0.56	0.56
BUBO Egg Numbers - MSSAY	CV	1	0.56	-	0.56	0.56
BUBO Egg Numbers - ASAY	CV	4	0.45	0.24	0.16	0.71
RALU J & A Detection Time - MSSWY	CV	35	0.62	0.44	0	1.69
RALU J & A Detection Time - MSSAY	CV	26	0.72	0.43	0	1.71
RALU J & A Detection Time - ASAY	CV	43	0.66	0.47	0	1.71
PSMA Larvae Detection Time - MSSWY	CV	19	0.66	0.39	0	1.36
PSMA Larvae Detection Time - MSSAY	CV	12	0.71	0.33	0	1.1
PSMA Larvae Detection Time - ASAY	CV	15	0.72	0.4	0	1.38
RALU Larvae Detection Time - MSSWY	CV	38	0.67	0.43	0	1.65
RALU Larvae Detection Time - MSSAY	CV	22	0.8	0.5	0	1.72
RALU Larvae Detection Time - ASAY	CV	41	0.73	0.46	0	1.72

Table 4B Continued

Species Variable[1]	Method of Evaluation[2]	N[3]	X[4]	SD[4]	Min[4]	Max[4]
BUBO Larvae Detection Time - MSSWY	CV	5	0.74	0.43	0	1.04
BUBO Larvae Detection Time - MSSAY	CV	3	1.23	0.21	1.04	1.46
BUBO Larvae Detection Time - ASAY	CV	19	0.77	0.44	0	1.46
AMMA Larvae Detection Time - MSSWY	CV	8	0.74	0.43	0	1.38
AMMA Larvae Detection Time - MSSAY	CV	6	0.8	0.53	0	1.52
AMMA Larvae Detection Time - ASAY	CV	15	0.5	0.52	0	1.52
BUBO Egg Detection Time - MSSWY	CV	1	0.76	-	0.76	0.76
BUBO Egg Detection Time - MSSAY	CV	1	0.76	-	0.76	0.76
BUBO Egg Detection Time - ASAY	CV	3	0.54	0.47	0	0.85
RALU Juv & Adult Numbers - MSSWY	CV	61	0.77	0.42	0	1.71
RALU Juv & Adult Numbers - MSSAY	CV	41	0.8	0.55	0	2.88
RALU Juv & Adult Numbers - ASAY	CV	129	0.68	0.48	0	2.88
AMTI Larvae Detection Time - MSSWY	CV	11	0.78	0.29	0.38	1.33
AMTI Larvae Detection Time - MSSAY	CV	6	0.78	0.32	0.38	1.18
AMTI Larvae Detection Time - ASAY	CV	7	0.86	0.36	0.38	1.35
PSMA Juv & Adult Numbers - MSSWY	CV	21	0.83	0.55	0	2.37
PSMA Juv & Adult Numbers - MSSAY	CV	12	0.99	0.74	0	2.56
PSMA Juv & Adult Numbers - ASAY	CV	13	1.03	0.71	0	2.56
AMMA Egg Detection Time - MSSWY	CV	1	0.94	-	0.94	0.94
AMMA Egg Detection Time - MSSAY	CV	1	0.94	-	0.94	0.94
AMMA Egg Detection Time - ASAY	CV	0	-	-	-	-
BUBO Juvs & Adults - MSSWY	CV	5	0.96	0.58	0	1.56
BUBO Juvs & Adults - MSSAY	CV	3	0.94	0.9	0	1.8
BUBO Juvs & Adults - ASAY	CV	35	0.87	0.62	0	1.95
RALU Egg Numbers - MSSWY	CV	0	-	-	-	-
RALU Egg Numbers - MSSAY	CV	0	-	-	-	-
RALU Egg Numbers - ASAY	CV	24	0.31	0.28	0	1.1
AMMA Egg Numbers - MSSWY	CV	0	-	-	-	-
AMMA Egg Numbers - MSSAY	CV	0	-	-	-	-
AMMA Egg Numbers - ASAY	CV	6	0.66	0.47	0.16	1.2
BUBO J & A Detection Time - MSSWY	CV	0	-	-	-	-
BUBO J & A Detection Time - MSSAY	CV	0	-	-	-	-
BUBO J & A Detection Time - ASAY	CV	1	1.25	-	1.25	1.25
AMMA Juv & Adult Numbers - MSSWY	CV	0	-	-	-	-
AMMA Juv & Adult Numbers - MSSAY	CV	0	-	-	-	-
AMMA Juv & Adult Numbers - ASAY	CV	0	-	-	-	-

Table 4B Continued

Species Variable[1]	Method of Evaluation[2]	N[3]	X[4]	SD[4]	Min[4]	Max[4]
AMMA J&A Detection Time - MSSWY	CV	0	-	-	-	-
AMMA J&A Detection Time - MSSAY	CV	0	-	-	-	-
AMMA J&A Detection Time - ASAY	CV	0	-	-	-	-
AMTI Egg Numbers - MSSWY	CV	0	-	-	-	-
AMTI Egg Numbers - MSSAY	CV	0	-	-	-	-
AMTI Egg Numbers - ASAY	CV	0	-	-	-	-
AMTI Egg Detection Time - MSSWY	CV	0	-	-	-	-
AMTI Egg Detection Time - MSSAY	CV	0	-	-	-	-
AMTI Egg Detection Time - ASAY	CV	0	-	-	-	-
PSMA Egg Numbers - MSSWY	CV	0	-	-	-	-
PSMA Egg Numbers - MSSAY	CV	0	-	-	-	-
PSMA Egg Numbers - ASAY	CV	0	-	-	-	-
PSMA Egg Detection Time - MSSWY	CV	0	-	-	-	-
PSMA Egg Detection Time - MSSAY	CV	0	-	-	-	-
PSMA Egg Detection Time - ASAY	CV	0	-	-	-	-
RALU Egg Detection Time - MSSWY	CV	0	-	-	-	-
RALU Egg Detection Time - MSSAY	CV	0	-	-	-	-
RALU Egg Detection Time - ASAY	CV	0	-	-	-	-

[1] Variables are sorted in descending order from those with higher of levels of precision to those with lower levels of precision on the MSSWY method of calculation. MSSWY indicates values were calculated only from multiple surveys of a site conducted within a single year. MSSAY indicates values were calculated from all surveys at sites with multiple surveys conducted within at least one of the years of sampling (corresponds to shaded Site IDs in Table 1). ASAY indicates values were calculated from all surveys conducted across all years (i.e. sites were surveyed multiple times either within years, between years, or both corresponding to all Site IDs listed in Table 1). AMMA = Long-toed Salamander (*Ambystoma macrodactylum*), AMTI = Tiger Salamander (*Ambystoma tigrinum)*, BUBO = Western Toad (*Bufo boreas*), PSMA = Boreal Chorus Frog (*Pseudacris maculata*), RALU = Columbia Spotted Frog (*Rana luteiventris*), Terrestrial Gartersnake (*Thamnophis elegans*), THSI = Common Gartersnake (*Thamnophis sirtalis*).

[2] CV values simply represent the standard deviation divided by the mean. Thus, a CV = 1 indicates the standard deviation of the responses was equivalent in magnitude to the mean value of the responses.

[3] N indicates numbers of sites for which CV could be calculated because of multiple surveys evaluating the variable.

[4] X, SD, Min, and Max are the overall mean, standard deviation, minimum, and maximum values for CV values calculated for sites with multiple surveys where the variable was documented.

Table 5

Covariates used in candidate models

Variable	Type	Variable Description (units)
		Site Level Covariates
Burn	Categorical	Vegetation around site recently burned with wildfire (0, 1)
BWFish [1]	Categorical	Species breeding with fish (0, 1)
Dammed	Categorical	Water at site dammed or diverted (0, 1)
Date [1]	Continuous	Julian date within year of survey (3 digits)
DForest	Continuous	Distance from edge of site to nearest forest with closed canopy (m)
Elevation	Continuous	Elevation of site in (ft)
EvegA [1]	Continuous	Estimated area of emergent vegetation at site (m^2)
Expos	Continuous	Southern exposure of shallows - average of 8 inclinations to horizon at 20 degree intervals between compass bearings of 70 and 210 degrees (scale = 0-90)
Fish [1]	Categorical	Fish detected at site but not necessarily breeding with species (0, 1)
Grazing [1]	Categorical	Heavy structural or water quality impacts to site from cattle (0, 1)
H20Perm	Categorical	Water at site is permanent (0, 1)
Number [1]	Continuous	Average number of life history stage of species detected at site by surveyors who detected the life history stage
Sedge1	Categorical	Dominant emergent vegetation is sedge (0, 1)
Shallow [1]	Categorical	Shallows present on northern shoreline of site (0, 1)
SiltMud	Categorical	Silt or mud is the dominant substrate (0, 1)
Strata	Continuous	Sample strata in which the site is found (1-11) (see figure 1)
Timber	Categorical	Forest around site recently harvested (0, 1)
		Watershed Level Covariates
NSR	Continuous	Number of lentic sites capable of supporting reproduction
%Breed	Continuous	Percent of lentic sites where individual species were detected breeding
%Dam	Continuous	Percent of lentic sites supporting reproduction with structure or water quality heavily impacted by grazing
%Detect	Continuous	Percent of lentic sites where individual species were detected
%Fish	Continuous	Percent of permanent lentic sites with fish detected
%Grazing	Continuous	Percent of lentic sites supporting reproduction with structure or water quality heavily impacted by grazing
%PEveg	Continuous	Percent of permanent lentic sites with emergent vegetation present
%Timber	Continuous	Percent of lentic sites supporting reproduction with forest around site recently harvested
		Sampling Covariates
Surveyor	Categorical	Experienced surveyor (0, 1)

[1] Indicates that although variable might otherwise be considered a sampling covariate, it was considered a site level covariate because multiple surveys within a year were conducted within 2 days of one another and analyses were only for single season models.

Table 6A

Candidate models for *Ambystoma macrodactylum* Larvae ranked by level of support of data for candidate model.

Candidate Model Description and Notation	AIC	Δ AIC	AIC weight	Model Likelihood	No. Parameters
Base Model with all Impacts = (ψDForest+Elevation+EvegA+Expos+NSR+%Breed+Strata+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing+Timber+%Timber) (ρDate+EvegA+Number+Surveyor)	780.74	0.00	0.60	0.36	21
Base Model with all Impacts and Only Larval Numbers Affecting Detectability = (ψDForest+Elevation+EvegA+Expos+NSR+%Breed+Strata+Dammed+%Dam+BWFish+Fish+%Fish+ Grazing+%Grazing+Timber+%Timber) (ρNumber)	781.93	1.19	0.33	0.20	18
Base Model with Fish as only Impact = (ψDForest+Elevation+EvegA+Expos+NSR+%Breed+Strata+BWFish+Fish+%Fish) (ρDate+EvegA+Number+Surveyor)	784.98	4.24	0.07	0.04	16
Base Model with Grazing as only Impact = (ψDForest+Elevation+EvegA+Expos+NSR+%Breed+Strata+Grazing+%Grazing) (ρDate+EvegA+Number+Surveyor)	796.51	15.77	0.00	0.00	15
Base Model with Damming or Diverting of Water as only Impact = (ψDForest+Elevation+EvegA+Expos+NSR+%Breed+Strata+Dammed+%Dam) (ρDate+EvegA+Number+Surveyor)	796.91	16.17	0.00	0.00	15
Base Model without Impacts = (ψDForest+Elevation+EvegA+Expos+NSR+%Breed+Strata) (ρDate+EvegA+Number+Surveyor)	798.59	17.85	0.00	0.00	13
Distance to Forest, site availability, landscape occupancy,with Local Fish Impacts Only = (ψDForest+Elevation+NSR+%Breed+Strata+BWFish) (ρNumber)	799.04	18.30	0.00	0.00	9
Distance to Forest, site availability, landscape occupancy,with Watershed Fish Impacts Only = (ψDForest+Elevation+NSR+%Breed+Strata+%Fish) (ρNumber)	802.74	22.00	0.00	0.00	9
Distance to Forest, site availability, landscape occupancy, with Local Fish Impacts Only = (ψDForest+Elevation+NSR+%Breed+Strata+Fish) (ρNumber)	803.01	22.27	0.00	0.00	9
Base Model with Timber Harvest as only Impact = (ψDForest+Elevation+EvegA+Expos+NSR+%Breed+Strata+Timber+%Timber) (ρDate+EvegA+Number+Surveyor)	804.16	23.42	0.00	0.00	15
Base Model with all Impacts and Only Date Affecting Detectability = (ψDForest+Elevation+EvegA+Expos+NSR+%Breed+Strata+Dammed+%Dam+BWFish+Fish+%Fish+ Grazing+%Grazing+Timber+%Timber) (ρDate)	1011.68	230.94	0.00	0.00	18
Base Model with all Impacts and Only Surveyor Affecting Detectability = (ψDForest+Elevation+EvegA+Expos+NSR+%Breed+Strata+Dammed+%Dam+BWFish+Fish+%Fish+ Grazing+%Grazing+Timber+%Timber) (ρSurveyor)	1022.91	242.17	0.00	0.00	18
Base Model with all Impacts and Only Emergent Vegetation Area Affecting Detectability = (ψDForest+Elevation+EvegA+Expos+NSR+%Breed+Strata+Dammed+%Dam+BWFish+Fish+%Fish+ Grazing+%Grazing+Timber+%Timber) (ρEvegA)	1025.40	244.66	0.00	0.00	18
Constant occupancy and detection = (ψ.) (ρ.)	1357.56	576.82	0.00	0.00	2
2 unidentified occupancy groups and constant detection = (ψ 2 groups) (ρ.)	1359.56	578.82	0.00	0.00	4
Constant occupancy and survey specific detection = (ψ.) (ρsurvey specific)	1371.65	590.91	0.00	0.00	23

ψ = probability of site occupancy, ρ = probability of detection, . = constant

Table 6B

Candidate models for *Ambystoma tigrinum* Larvae ranked by level of support of data for candidate model.

Candidate Model Description and Notation (* Indicates non A Priori model)	**AIC**	**Δ AIC**	**AIC weight**	**Model Likelihood**	**No. Parameters**
Base Model without Impacts = (ψElevation+NSR+%Breed) (ρNumber+Surveyor)	219.76	0.00	0.43	0.18	7
Base Model with Only Larval Numbers Affecting Detectability = (ψElevation+NSR+%Breed) (ρNumber)	220.70	0.94	0.27	0.11	6
***Base Model with only Local Fish Impacts and Only Larval Numbers Affecting Detectability =** (ψElevation+NSR+%Breed+Fish) (ρNumber)	221.48	1.72	0.18	0.08	7
***Base Model with only Landscape Fish Impacts and Only Larval Numbers Affecting Detectability =** (ψElevation+NSR+%Breed+%Fish) (ρNumber)	224.38	4.62	0.04	0.02	7
Base Model with Grazing as only Impact = (ψElevation+NSR+%Breed+Grazing+%Grazing) (ρNumber+Surveyor)	225.31	5.55	0.03	0.01	9
Base Model with Damming or Diverting of Water as only Impact = (ψElevation+NSR+%Breed+Dammed+%Dam) (ρNumber+Surveyor)	225.47	5.71	0.02	0.01	9
***Base Model with Local and Landscape Fish Impacts and Larval Numbers Affecting Detectability =** (ψElevation+NSR+%Breed+Fish+%Fish) (ρNumber)	226.05	6.29	0.02	0.01	8
Base Model with Fish as only Impact = (ψElevation+NSR+%Breed+BWFish+Fish+%Fish) (ρNumber+Surveyor)	227.77	8.01	0.01	0.00	10
Base Model with all Impacts and Only Larval Numbers Affecting Detectability = (ψElevation+NSR+%Breed+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing) (ρNumber)	231.86	12.1	0.00	0.00	13
Base Model with all Impacts Except Timber = (ψElevation+NSR+%Breed+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing) (ρNumber+Surveyor)	232.67	12.91	0.00	0.00	14
Base Model with all Impacts and Only Surveyor Affecting Detectability = (ψElevation+NSR+%Breed+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing) (ρSurveyor)	308.61	88.85	0.00	0.00	13
2 unidentified occupancy groups and constant detection = (ψ 2 groups) (ρ.)	336.23	116.47	0.00	0.00	4
Constant occupancy and detection = (ψ.) (ρ.)	366.50	146.74	0.00	0.00	2
Constant occupancy and survey specific detection = (ψ.) (ρsurvey specific)	416.21	196.45	0.00	0.00	23

ψ = probability of site occupancy, ρ = probability of detection, . = constant

Table 6C

Candidate models for *Bufo boreas* Larvae ranked by level of support of data for candidate model.

Candidate Model Description and Notation	AIC	Δ AIC	AIC weight	Model Likelihood	No. Parameters
Base Model with all Impacts = (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing+Timber+%Timber) (ρDate+EvegA+Number+Surveyor)	189.12	0.00	0.99	0.99	24
Base Model with Fish as only Impact = (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed+BWFish+Fish+%Fish) (ρDate+EvegA+Number+Surveyor)	206.56	17.44	0.00	0.00	18
Base Model with Damming or Diverting of Water as only Impact = (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed+Dammed+%Dam) (ρDate+EvegA+Number+Surveyor)	217.79	28.67	0.00	0.00	17
Base Model without Impacts = (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed) (ρDate+EvegA+Number+Surveyor)	219.91	30.79	0.00	0.00	15
Base Model with Grazing as only Impact = (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed+Grazing+%Grazing) (ρDate+EvegA+Number+Surveyor)	223.19	34.07	0.00	0.00	17
Base Model with Timber Harvest as only Impact = (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed+Timber+%Timber) (ρDate+EvegA+Number+Surveyor)	223.58	34.46	0.00	0.00	17
Base Model with all Impacts and only Number of Larvae Affecting Detectability = (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing+Timber+%Timber) (ρNumber)	225.68	36.56	0.00	0.00	21
Site Exposure and Number of Larvae Affecting Detectability = (ψBurn+Expos+Timber+%Timber) (ρNumber)	229.96	40.84	0.00	0.00	7
Site Exposure = (ψBurn+Expos+Timber+%Timber) (ρDate+EvegA+Number+Surveyor)	233.55	44.43	0.00	0.00	10
Base Model with all Impacts and only Date Affecting Detectability = (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing+Timber+%Timber) (ρDate)	335.35	146.23	0.00	0.00	21
Base Model with all Impacts and only Area of Emergent Vegetation Affecting Detectability = (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing+Timber+%Timber) (ρEvegA)	342.47	153.35	0.00	0.00	21
Base Model with all Impacts and only Surveyor Affecting Detectability = (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing+Timber+%Timber) (ρSurveyor)	342.62	153.5	0.00	0.00	21
Constant occupancy and survey specific detection = (ψ.) (ρsurvey specific)	462.39	273.27	0.00	0.00	2
2 unidentified occupancy groups and constant detection = (ψ 2 groups) (ρ.)	466.39	277.27	0.00	0.00	4
Constant occupancy and survey specific detection = (ψ.) (ρsurvey specific)	471.79	282.67	0.00	0.00	23

ψ = probability of site occupancy, ρ = probability of detection, . = constant

Table 6D

Candidate models for *Bufo boreas* Juveniles and Adults ranked by level of support of data for candidate model.

Candidate Model Description and Notation (* Indicates non A Priori model)	AIC	Δ AIC	AIC weight	Model Likelihood	No. Parameters
***Base Model with Watershed Grazing as only Impact =** (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed+%Grazing) (ρDate+EvegA+Number+Surveyor)	518.85	0.00	0.66	0.44	16
Base Model with Grazing as only Impact = (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed+Grazing+%Grazing) (ρDate+EvegA+Number+Surveyor)	521.36	2.51	0.19	0.13	17
***Base Model with Grazing as only Impact & only No. of Juvs & Adults Affecting Detectability =** (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed+Grazing+%Grazing) (ρNumber)	521.91	3.06	0.14	0.09	14
Base Model with Fish as only Impact = (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed+BWFish+Fish+%Fish) (ρDate+EvegA+Number+Surveyor)	529.66	10.81	0.00	0.00	18
Base Model with Timber Harvest as only Impact = (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed+Timber+%Timber) (ρDate+EvegA+Number+Surveyor)	536.30	17.45	0.00	0.00	17
***Base Model with Local Grazing as only Impact =** (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed+Grazing) (ρDate+EvegA+Number+Surveyor)	537.20	18.35	0.00	0.00	16
Base Model with all Impacts and only Number of Juveniles or Adults Affecting Detectability = (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing+Timber+%Timber) (ρNumber)	540.62	21.77	0.00	0.00	21
Base Model without Impacts = (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed) (ρDate+EvegA+Number+Surveyor)	541.43	22.58	0.00	0.00	15
Base Model with all Impacts = (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing+Timber+%Timber) (ρDate+EvegA+Number+Surveyor)	542.40	23.55	0.00	0.00	24
Base Model with all Impacts and only Surveyor Affecting Detectability = (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing+Timber+%Timber) (ρSurveyor)	549.58	30.73	0.00	0.00	21
Base Model with all Impacts and only Date Affecting Detectability = (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing+Timber+%Timber) (ρDate)	550.08	31.23	0.00	0.00	21
Base Model with Damming or Diverting of Water as only Impact = (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed+Dammed+%Dam) (ρDate+EvegA+Number+Surveyor)	552.30	33.45	0.00	0.00	17
Base Model with all Impacts and only Area of Emergent Vegetation Affecting Detectability = (ψBurn+Date+DForest+Elevation+EvegA+Expos+NSR+Shallow+%Breed+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing+Timber+%Timber) (ρEvegA)	553.17	34.32	0.00	0.00	21
Constant occupancy and detection = (ψ.) (ρ.)	619.52	100.67	0.00	0.00	2
2 unidentified occupancy groups and constant detection = (ψ 2 groups) (ρ.)	623.52	104.67	0.00	0.00	4
Constant occupancy and survey specific detection = (ψ.) (ρsurvey specific)	644.91	126.06	0.00	0.00	23

ψ = probability of site occupancy, ρ = probability of detection, . = constant

Table 6E

Candidate models for *Pseudacris maculata* Larvae ranked by level of support of data for candidate model.

Candidate Model Description and Notation (* Indicates non A Priori model)	**AIC**	**Δ AIC**	**AIC weight**	**Model Likelihood**	**No. Parameters**
***Base Model without impacts and only Number of Larvae Affecting Detectability =** (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed) (ρNumber)	278.81	0.00	0.64	0.41	11
***Base Model with Grazing as only Impact and only Number of Larvae Affecting Detectability =** (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed+Grazing+%Grazing) (ρDate+EvegA+Number+Surveyor)	281.39	2.58	0.18	0.11	13
***Base Model with Damming Water as only Impact & only Number of Larvae Affecting Detectability** = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed+Dammed+%Dam) (ρDate+EvegA+Number+Surveyor)	281.39	2.58	0.18	0.11	13
Base Model with all Impacts and only Number of Larvae Affecting Detectability = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing) (ρNumber)	289.80	10.99	0.00	0.00	18
Base Model with Damming or Diverting of Water as only Impact = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed+Dammed+%Dam) (ρDate+EvegA+Number+Surveyor)	290.91	12.1	0.00	0.00	16
Base Model with Grazing as only Impact = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed+Grazing+%Grazing) (ρDate+EvegA+Number+Surveyor)	294.25	15.44	0.00	0.00	16
Base Model without impacts = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed) (ρDate+EvegA+Number+Surveyor)	299.67	20.86	0.00	0.00	14
Base Model with all Impacts = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing) (ρDate+EvegA+Number+Surveyor)	300.23	21.42	0.00	0.00	21
Base Model with Fish as only Impact = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%BreedBWFish+Fish+%Fish) (ρDate+EvegA+Number+Surveyor)	305.49	26.68	0.00	0.00	17
Base Model with all Impacts and only Date Affecting Detectability = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing) (ρDate)	386.82	108.01	0.00	0.00	18
Base Model with all Impacts and only Area of Emergent Vegetation Affecting Detectability = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing) (ρEvegA)	392.73	113.92	0.00	0.00	18
2 unidentified occupancy groups and constant detection = (ψ 2 groups) (ρ.)	403.17	124.36	0.00	0.00	4
Constant occupancy and detection = (ψ.) (ρ.)	432.37	153.56	0.00	0.00	2
Base Model with all Impacts and only Surveyor Affecting Detectability = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing) (ρSurveyor)	453.78	174.97	0.00	0.00	18
Constant occupancy and survey specific detection = (ψ.) (ρsurvey specific)	456.64	177.83	0.00	0.00	23

ψ = probability of site occupancy, ρ = probability of detection, . = constant

Table 6F

Candidate models for *Pseudacris maculata* Juveniles and Adults ranked by level of support of data for candidate model.

Candidate Model Description and Notation (* Indicates non A Priori model) ψ = probability of site occupancy, ρ = probability of detection, . = constant	**AIC**	**Δ AIC**	**AIC weight**	**Model Likelihood**	**No. Parameters**
***Base Model with Grazing as only Impact and only No. Juveniles or Adults Affecting Detectability=** (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed+Grazing+%Grazing) (ρNumber)	281.28	0.00	0.89	0.80	13
***Base Model with Watershed Level Grazing as only Impact & Juvs Adults Affecting Detectability =** (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed+%Grazing) (ρNumber)	285.63	4.35	0.10	0.09	12
***Base Model without Impacts and only Numbers of Juveniles or Adults Affecting Detectability =** (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed) (ρNumber)	292.82	11.54	0.00	0.00	11
***Base Model with Site Level Grazing as only Impact & Juvs Adults Affecting Detectability =** (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed+Grazing) (ρNumber)	293.85	12.57	0.00	0.00	12
***Base Model with Fish as only Impact & Juvs Adults Affecting Detectability =** (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed+ BWFish+Fish+%Fish) (ρNumber)	294.48	13.20	0.00	0.00	14
Base Model with Damming as only Impact & Numbers of Juveniles & Adults Affecting Detectability = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed+Dammed+%Dam) (ρNumber)	295.06	13.78	0.00	0.00	13
Base Model with all Impacts and only Numbers of Juveniles and Adults Affecting Detectability = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed+Dammed+%Dam+BWFish+Fish+ %Fish+Grazing+%Grazing) (ρNumber)	299.94	18.66	0.00	0.00	18
2 unidentified occupancy groups and constant detection = (ψ 2 groups) (ρ.)	324.39	43.11	0.00	0.00	4
Base Model without impacts = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed) (ρDate+EvegA+Number+Surveyor)	327.03	45.75	0.00	0.00	14
Base Model with Grazing as only Impact = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed+Grazing+%Grazing) (ρDate+EvegA+Number+Surveyor)	329.68	48.4	0.00	0.00	16
Base Model with Damming or Diverting of Water as only Impact = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed+Dammed+%Dam) (ρDate+EvegA+Number+Surveyor)	329.8	48.52	0.00	0.00	16
Base Model with Fish as only Impact = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%BreedBWFish+Fish+%Fish) (ρDate+EvegA+Number+Surveyor)	332.45	51.17	0.00	0.00	17
Constant occupancy and detection = (ψ.) (ρ.)	333.87	52.59	0.00	0.00	2
Base Model with all Impacts = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed+Dammed+%Dam+BWFish+Fish+ %Fish+Grazing+%Grazing) (ρDate+EvegA+Number+Surveyor)	334.42	53.04	0.00	0.00	21
Base Model with all Impacts and only Area of Emergent Vegetation Affecting Detectability = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed+Dammed+%Dam+BWFish+Fish+ %Fish+Grazing+%Grazing) (ρEvegA)	339.91	58.63	0.00	0.00	18
Base Model with all Impacts and only Date Affecting Detectability = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed+Dammed+%Dam+BWFish+Fish+ %Fish+Grazing+%Grazing) (ρDate)	339.97	58.69	0.00	0.00	18
Base Model with all Impacts and only Surveyor Affecting Detectability = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+SiltMud+%Breed+Dammed+%Dam+BWFish+Fish+ %Fish+Grazing+%Grazing) (ρSurveyor)	342.44	61.16	0.00	0.00	18
Constant occupancy and survey specific detection = (ψ.) (ρsurvey specific)	361.6	80.32	0.00	0.00	23

Table 6G

Candidate models for *Rana luteiventris* Larvae ranked by level of support of data for candidate model.

Candidate Model Description and Notation ψ = probability of site occupancy, ρ = probability of detection, . = constant	**AIC**	**Δ AIC**	**AIC weight**	**Model Likelihood**	**No. Parameters**
Base Model with all Impacts = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+Sedge1+Shallow+SiltMud+%Breed+%PEveg+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing+Timber+%Timber) (ρDate+EvegA+Number+Surveyor)	1274.65	0.00	0.97	0.94	26
Base Model with Grazing as only Impact = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+Sedge1+Shallow+SiltMud+%Breed+%PEveg+Grazing+%Grazing) (ρDate+EvegA+Number+Surveyor)	1282.12	7.47	0.02	0.02	19
Base Model with Timber Harvest as only Impact = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+Sedge1+Shallow+SiltMud+%Breed+%PEveg+Timber+%Timber) (ρDate+EvegA+Number+Surveyor)	1286.27	11.62	0.00	0.00	19
Base Model with Fish as only Impact = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+Sedge1+Shallow+SiltMud+%Breed+%PEveg+BWFish+Fish+%Fish) (ρDate+EvegA+Number+Surveyor)	1288.15	13.50	0.00	0.00	20
Base Model with Damming or Diverting of Water as only Impact = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+Sedge1+Shallow+SiltMud+%Breed+%PEveg+Dammed+%Dam) (ρDate+EvegA+Number+Surveyor)	1288.82	14.17	0.00	0.00	19
Base Model with all Impacts and only Number of Larvae Affecting Detectability = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+Sedge1+Shallow+SiltMud+%Breed+%PEveg+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing+Timber+%Timber) (ρNumber)	1289.92	15.27	0.00	0.00	23
Base Model without impacts = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+Sedge1+Shallow+SiltMud+%Breed+%PEveg) (ρDate+EvegA+Number+Surveyor)	1292.58	17.93	0.00	0.00	17
Permanent Water, Eveg, and Landscape Fish with only Number of Larvae Affecting Detectability = (ψEvegA+NSR+Sedge1+%PEveg+%Fish) (ρNumber)	1303.33	28.68	0.00	0.00	8
Permanent Water, Eveg, and Local Fish with only Number of Larvae Affecting Detectability = (ψEvegA+NSR+Sedge1+%PEveg+Fish) (ρNumber)	1308.70	34.05	0.00	0.00	8
PermH20, Eveg, and Local & Landscape Fish with only No. of Larvae Affecting Detectability = (ψEvegA+NSR+Sedge1+%PEveg+Fish+%Fish) (ρNumber)	1321.62	46.97	0.00	0.00	9
Base Model with all Impacts and only Eveg Area Affecting Detectability = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+Sedge1+Shallow+SiltMud+%Breed+%PEveg+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing+Timber+%Timber) (ρEvegA)	1820.03	545.38	0.00	0.00	23
Base Model with all Impacts and only Surveyor Affecting Detectability = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+Sedge1+Shallow+SiltMud+%Breed+%PEveg+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing+Timber+%Timber) (ρSurveyor)	1833.85	559.20	0.00	0.00	23
Base Model with all Impacts and only Date Affecting Detectability = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+Sedge1+Shallow+SiltMud+%Breed+%PEveg+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing+Timber+%Timber) (ρDate)	1835.94	561.29	0.00	0.00	23
2 unidentified occupancy groups and constant detection = (ψ 2 groups) (ρ.)	2150.68	876.03	0.00	0.00	4
Constant occupancy and detection = (ψ.) (ρ.)	2179.38	904.73	0.00	0.00	2
Constant occupancy and survey specific detection = (ψ.) (ρsurvey specific)	2272.31	997.66	0.00	0.00	23

Table 6H

Candidate models for *Rana luteiventris* Juveniles and Adults ranked by level of support of data for candidate model.

Candidate Model Description and Notation	AIC	Δ AIC	AIC weight	Model Likelihood	No. Parameters
Base Model with Damming or Diverting of Water as only Impact = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+Sedge1+Shallow+SiltMud+%Breed+%PEveg+Dammed+%Dam) (ρDate+EvegA+Number+Surveyor)	1173.34	0.00	0.37	0.14	19
Base Model without impacts = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+Sedge1+Shallow+SiltMud+%Breed+%PEveg) (ρDate+EvegA+Number+Surveyor)	1174.00	0.66	0.27	0.10	17
Base Model with Grazing as only Impact = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+Sedge1+Shallow+SiltMud+%Breed+%PEveg+Grazing+%Grazing) (ρDate+EvegA+Number+Surveyor)	1174.90	1.56	0.17	0.06	19
Base Model with Fish as only Impact = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+Sedge1+Shallow+SiltMud+%Breed+%PEveg+BWFish+Fish+%Fish) (ρDate+EvegA+Number+Surveyor)	1175.49	2.15	0.13	0.05	19
Base Model with all Impacts = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+Sedge1+Shallow+SiltMud+%Breed+%PEveg+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing+Timber+%Timber) (ρDate+EvegA+Number+Surveyor)	1177.98	4.64	0.04	0.01	25
Base Model with Timber Harvest as only Impact = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+Sedge1+Shallow+SiltMud+%Breed+%PEveg+Timber+%Timber) (ρDate+EvegA+Number+Surveyor)	1178.60	5.26	0.03	0.01	19
Base Model with all Impacts and only Number of Juveniles and Adults Affecting Detectability = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+Sedge1+Shallow+SiltMud+%Breed+%PEveg+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing+Timber+%Timber) (ρNumber)	1210.27	36.93	0.00	0.00	22
Base Model with all Impacts and only Eveg Area Affecting Detectability = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+Sedge1+Shallow+SiltMud+%Breed+%PEveg+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing+Timber+%Timber) (ρEvegA)	2435.66	1262.32	0.00	0.00	22
2 unidentified occupancy groups and constant detection = (ψ 2 groups) (ρ.)	2592.34	1419.00	0.00	0.00	4
Constant occupancy and detection = (ψ.) (ρ.)	2674.63	1501.29	0.00	0.00	2
Constant occupancy and survey specific detection = (ψ.) (ρsurvey specific)	2813.70	1640.36	0.00	0.00	23
Base Model with all Impacts and only Date Affecting Detectability = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+Sedge1+Shallow+SiltMud+%Breed+%PEveg+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing+Timber+%Timber) (ρDate)	2851.03	1677.69	0.00	0.00	22
Base Model with all Impacts and only Surveyor Affecting Detectability = (ψDate+Elevation+EvegA+Expos+H20Perm+NSR+Sedge1+Shallow+SiltMud+%Breed+%PEveg+Dammed+%Dam+BWFish+Fish+%Fish+Grazing+%Grazing+Timber+%Timber) (ρSurveyor)	2856.78	1683.44	0.00	0.00	22

ψ = probability of site occupancy, ρ = probability of detection, . = constant

Table 6I

Candidate models for *Thamnophis elegans* Juveniles and Adults ranked by level of support of data for candidate model.

Candidate Model Description and Notation	AIC	Δ AIC	AIC weight	Model Likelihood	No. Parameters
Base Model without impacts = (ψElevation+Expos+NSR+%Detect+%RALUDetect+No_RALU_Larvae+No_RALU_JA) (ρDate+EvegA+Number+Surveyor)	513.37	0.00	0.81	0.66	13
Base Model with Grazing as only Impact = (ψElevation+Expos+NSR+%Detect+%RALUDetect+No_RALU_Larvae+No_RALU_JA+Grazing+%Grazing) (ρDate+EvegA+Number+Surveyor)	517.38	4.01	0.11	0.09	15
Base Model with Fish as only Impact = (ψElevation+Expos+NSR+%Detect+%RALUDetect+No_RALU_Larvae+No_RALU_JA+Fish+%Fish) (ρDate+EvegA+Number+Surveyor)	518.93	5.56	0.05	0.04	15
Base Model with Damming or Diverting of Water as only Impact = (ψElevation+Expos+NSR+%Detect+%RALUDetect+No_RALU_Larvae+No_RALU_JA+Dammed+%Dam) (ρDate+EvegA+Number+Surveyor)	520.51	7.14	0.02	0.02	15
Base Model with all Impacts = (ψElevation+Expos+NSR+%Detect+%RALUDetect+No_RALU_Larvae+No_RALU_JA+Dammed+%Dam+Fish+%Fish+Grazing+%Grazing) (ρDate+EvegA+Number+Surveyor)	523.85	10.48	0.00	0.00	19
Base Model with all Impacts and only Number of Juveniles and Adults Affecting Detectability= (ψElevation+Expos+NSR+%Detect+%RALUDetect+No_RALU_Larvae+No_RALU_JA+Dammed+%Dam+Fish+%Fish+Grazing+%Grazing) (ρNumber)	525.24	11.87	0.00	0.00	16
2 unidentified occupancy groups and constant detection = (ψ 2 groups) (ρ.)	1071.19	557.82	0.00	0.00	4
Constant occupancy and survey specific detection = (ψ.) (ρ survey specific)	1076.54	563.17	0.00	0.00	23
Constant occupancy and detection = (ψ.) (ρ.)	1096.14	582.77	0.00	0.00	2
Base Model with all Impacts and only Surveyor Affecting Detectability = (ψElevation+Expos+NSR+%Detect+%RALUDetect+No_RALU_Larvae+No_RALU_JA+Dammed+%Dam+Fish+%Fish+Grazing+%Grazing) (ρSurveyor)		Model Failed to Reach Numeric Convergence			
Base Model with all Impacts and only Date Affecting Detectability = (ψElevation+Expos+NSR+%Detect+%RALUDetect+No_RALU_Larvae+No_RALU_JA+Dammed+%Dam+Fish+%Fish+Grazing+%Grazing) (ρDate)		Model Failed to Reach Numeric Convergence			
Base Model with all Impacts and only Eveg Area Affecting Detectability = (ψElevation+Expos+NSR+%Detect+%RALUDetect+No_RALU_Larvae+No_RALU_JA+Dammed+%Dam+Fish+%Fish+Grazing+%Grazing) (ρEvegA)		Model Failed to Reach Numeric Convergence			

ψ = probability of site occupancy, ρ = probability of detection, . = constant

Table 6J

Candidate models for *Thamnophis sirtalis* Juveniles and Adults ranked by level of support of data for candidate model.

Candidate Model Description and Notation	AIC	Δ AIC	AIC weight	Model Likelihood	No. Parameters
Base Model with Grazing as only Impact = (ψElevation+Expos+NSR+%Detect+%RALUDetect+No_RALU_Larvae+No_RALU_JA+Grazing+%Grazing) (ρDate+EvegA+Number+Surveyor)	442.54	0.00	0.53	0.28	15
Base Model with Damming or Diverting of Water as only Impact = (ψElevation+Expos+NSR+%Detect+%RALUDetect+No_RALU_Larvae+No_RALU_JA+Dammed+%Dam) (ρDate+EvegA+Number+Surveyor)	444.19	1.65	0.23	0.12	15
Base Model without impacts = (ψElevation+Expos+NSR+%Detect+%RALUDetect+No_RALU_Larvae+No_RALU_JA) (ρDate+EvegA+Number+Surveyor)	444.85	2.31	0.17	0.09	13
Base Model with Fish as only Impact = (ψElevation+Expos+NSR+%Detect+%RALUDetect+No_RALU_Larvae+No_RALU_JA+Fish+%Fish) (ρDate+EvegA+Number+Surveyor)	446.53	3.99	0.07	0.04	15
Base Model with all Impacts = (ψElevation+Expos+NSR+%Detect+%RALUDetect+No_RALU_Larvae+No_RALU_JA+Dammed+%Dam+Fish+%Fish+Grazing+%Grazing) (ρDate+EvegA+Number+Surveyor)	451.99	9.45	0.00	0.00	19
Base Model with all Impacts and only Number of Juveniles and Adults Affecting Detectability= (ψElevation+Expos+NSR+%Detect+%RALUDetect+No_RALU_Larvae+No_RALU_JA+Dammed+%Dam+Fish+%Fish+Grazing+%Grazing) (ρNumber)	456.49	13.95	0.00	0.00	16
Prey Numbers and Numbers of THSI Affecting Detectability = (ψ%RALU_Detect+No_RALU_Larvae+No_RALU_JA+No_BUBO_Larvae) (ρNumber)	497.05	54.51	0.00	0.00	7
Base Model with all Impacts and only Eveg Area Affecting Detectability = (ψElevation+Expos+NSR+%Detect+%RALUDetect+No_RALU_Larvae+No_RALU_JA+Dammed+%Dam+Fish+%Fish+Grazing+%Grazing) (ρEvegA)	620.69	178.15	0.00	0.00	16
Base Model with all Impacts and only Date Affecting Detectability = (ψElevation+Expos+NSR+%Detect+%RALUDetect+No_RALU_Larvae+No_RALU_JA+Dammed+%Dam+Fish+%Fish+Grazing+%Grazing) (ρDate)	622.14	179.60	0.00	0.00	16
Base Model with all Impacts and only Surveyor Affecting Detectability = (ψElevation+Expos+NSR+%Detect+%RALUDetect+No_RALU_Larvae+No_RALU_JA+Dammed+%Dam+Fish+%Fish+Grazing+%Grazing) (ρSurveyor)	623.30	180.76	0.00	0.00	16
2 unidentified occupancy groups and constant detection = (ψ 2 groups) (ρ.)	824.74	382.20	0.00	0.00	4
Constant occupancy and detection = (ψ.) (ρ.)	830.37	387.83	0.00	0.00	2
Constant occupancy and survey specific detection = (ψ.) (ρ survey specific)	870.82	428.28	0.00	0.00	23

ψ = probability of site occupancy, ρ = probability of detection, . = constant

Table 7

Naïve site occupancy rates and estimated true site occupancy rates (ψ), which correct for imperfect detection of species, resulting from best fitting candidate models within the region in which data was used to test the models.

Species	Life History Stage	Naïve Site Occupancy Rate	Estimated True Site Occupancy Rate (ψ)
Ambystoma macrodactylum	Larvae	0.31	0.69
Ambystoma tigrinum	Larvae	0.15	0.48
Bufo boreas	Larvae	0.03	[1]
	Juveniles & Adults	0.04	[1]
Pseudacris maculata	Larvae	0.21	0.53
	Juveniles & Adults	0.13	0.40
Rana luteiventris	Larvae	0.27	0.85
	Juveniles & Adults	0.48	0.93
Thamnophis elegans	Juveniles & Adults	0.07	0.79
Thamnophis sirtalis	Juveniles & Adults	0.06	0.37

[1] Parameter unable to be estimated due to lack of data.

Figure 1.

Montana’s sampling scheme for assessing status and trends in lentic breeding amphibians using site occupancy rates as the major response variable. (A) Eleven geographic strata and up to three land ownership strata define 28 target populations from which 6^{th} code (12 digit) hydrologic unit code (HUC) watersheds are randomly selected during each status assessment period in order to infer changes in status for each species on regular or irregular time intervals as funding allows. (B) Watersheds completed for Montana’s lentic breeding amphibian baseline status assessment as of fall 2005, including lentic sites that have been surveyed multiple times within or between years from 1998-2004.

A

B

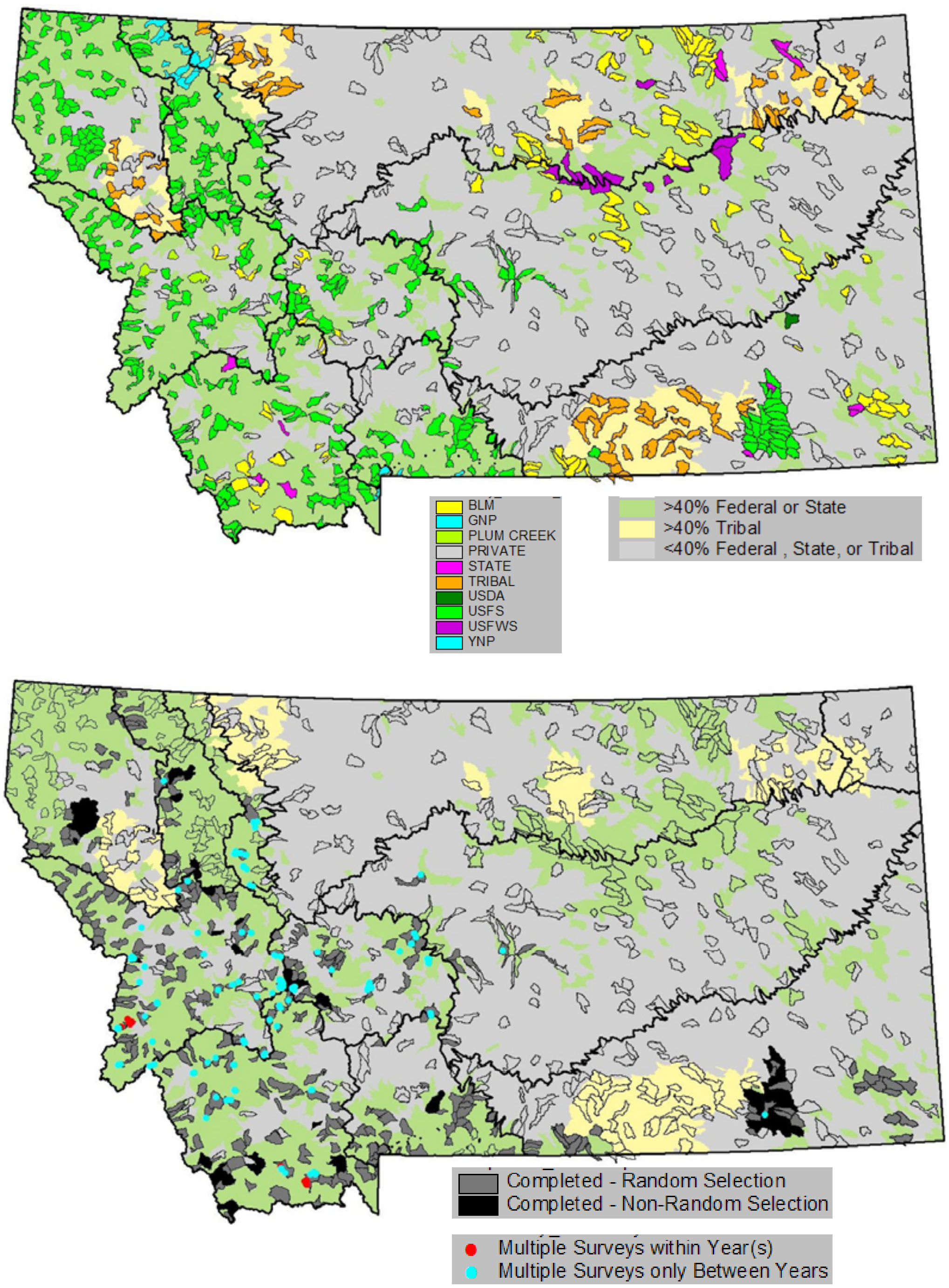
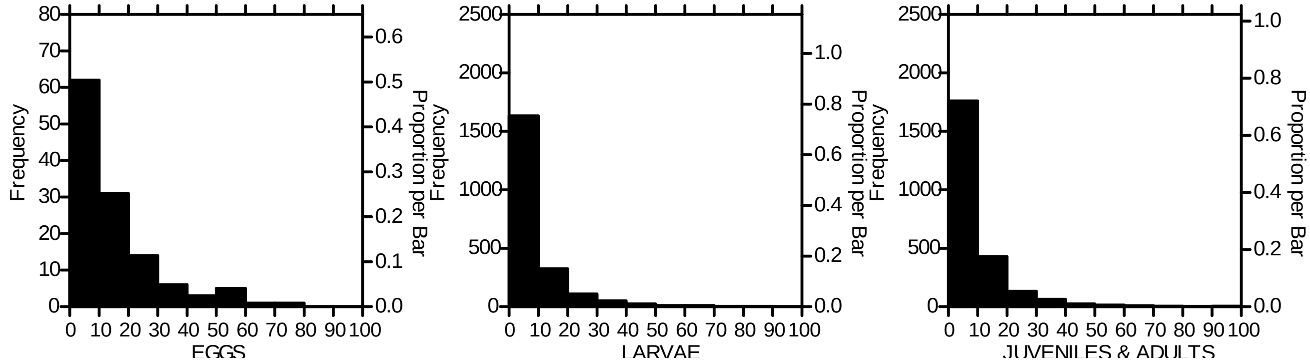


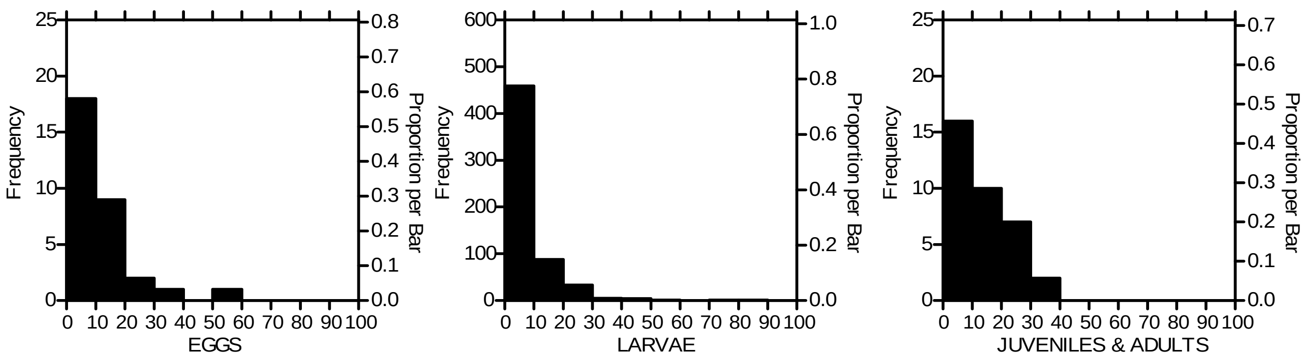
Figure 2

Histograms of time at first detection for eggs, larvae, and juveniles or adults of all amphibian and reptile species together and for individual species.

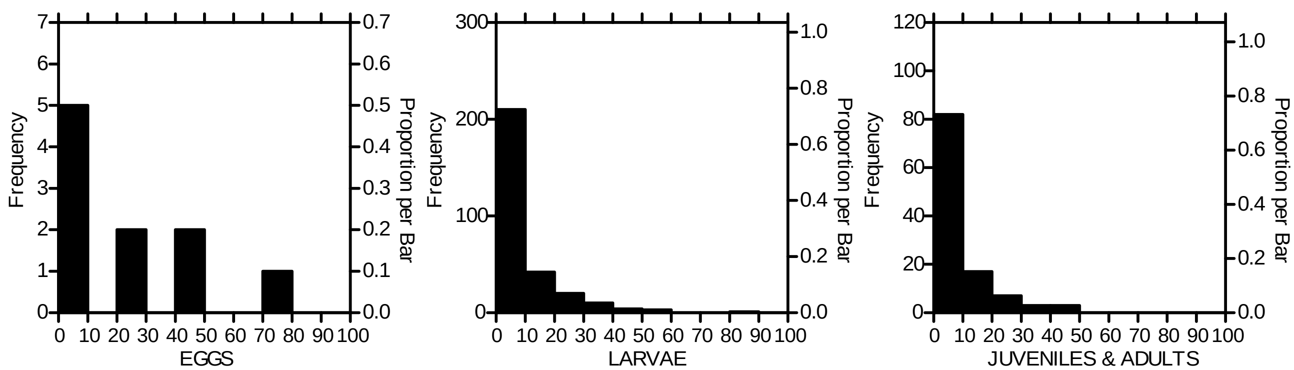
A – All Species



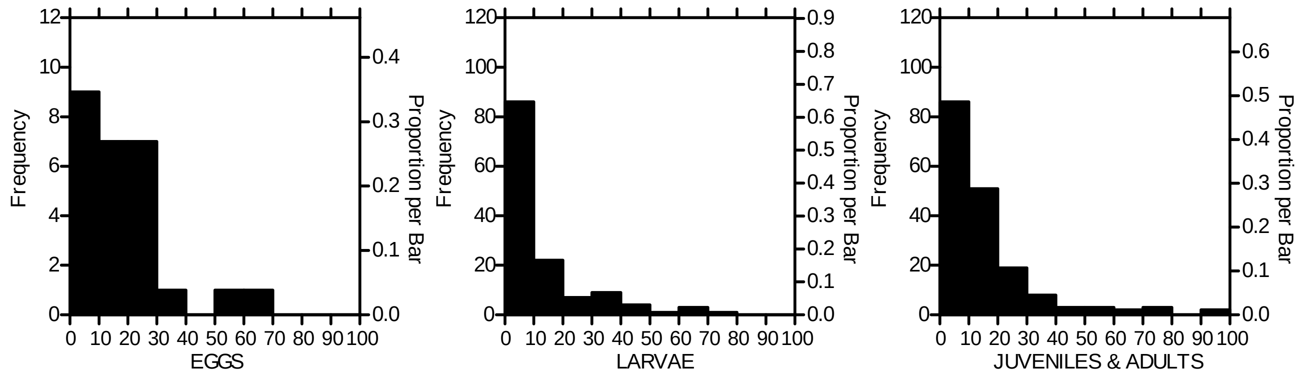
B – Long-toed Salamander (*Ambystoma macrodactylum*)



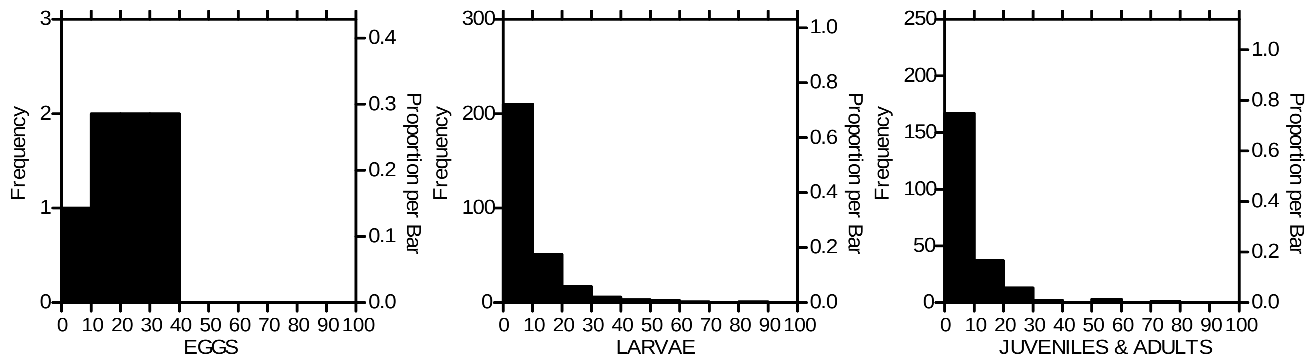
C – Tiger Salamander (*Ambystoma tigrinum*)



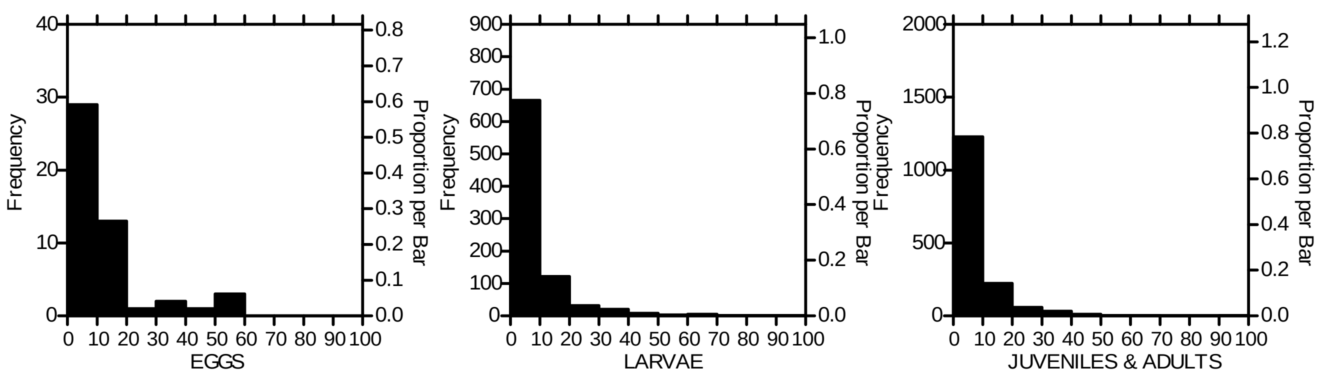
D – Western Toad (*Bufo boreas*)



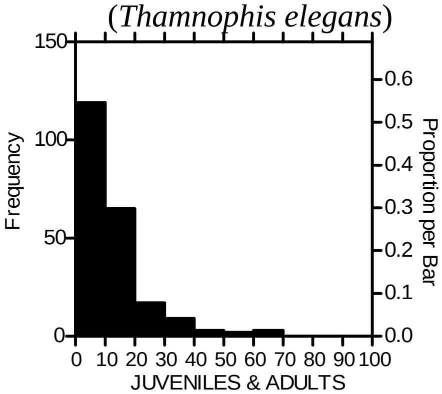
E – Boreal Chorus Frog (*Pseudacris maculata*)



F – Columbia Spotted Frog (*Rana luteiventris*)



G – Terrestrial Gartersnake (*Thamnophis elegans*)



H – Common Gartersnake (*Thamnophis sirtalis*)

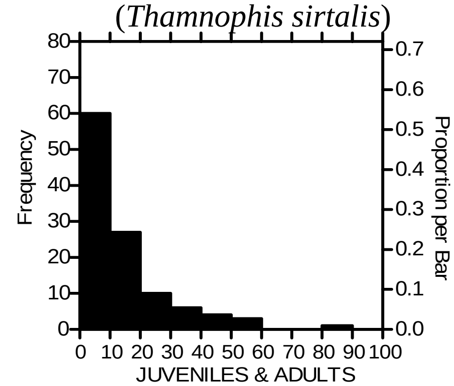
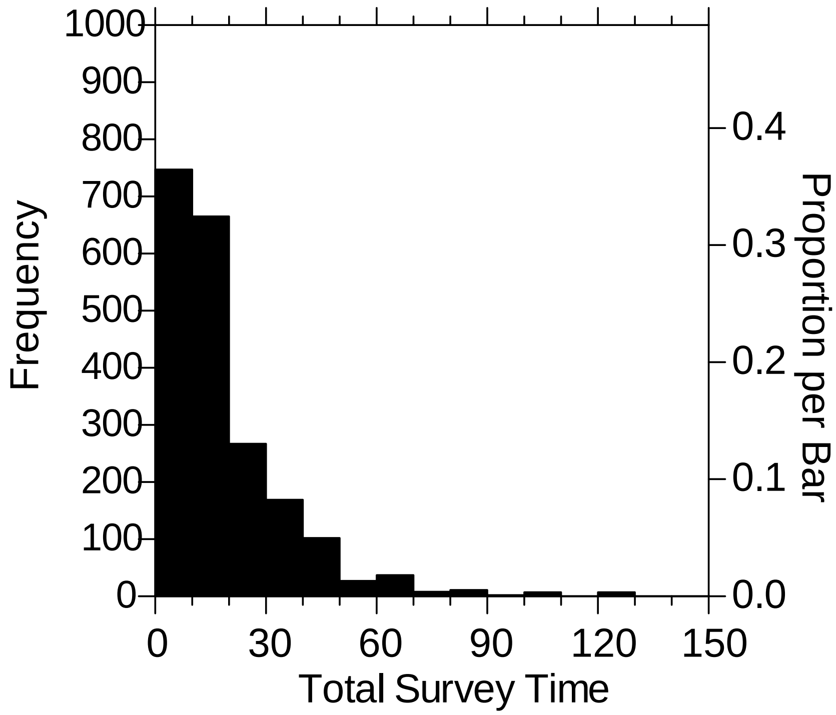


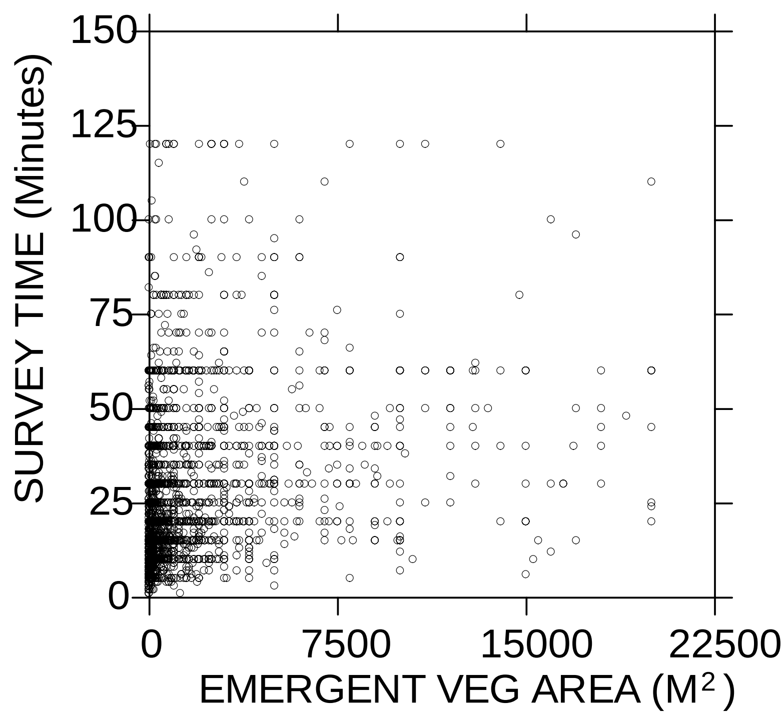
Figure 3

Survey times at (A) sites without species detected and at (B) all sites surveyed which had at least 1 square meter and less than 25,000 square meters of emergent vegetation and which were surveyed for less than 2 hours.

A



B



Appendix A
Site Data Form for Lentic Breeding Amphibian and Aquatic Reptile Surveys

Locality Information

Date	Observer(s)	Owner	Site Detection: Aerial Photo Topo Map NWI Map Incidental	GPS EPE

Strata Number	HUC Number	Site Number	State	County	Map Name

Locality	T	R	S	Section Description

Map Elevation FT	UTM Zone:	UTM East	UTM North	Survey Type 0 1 2 3 4 5 6 7 8

Habitat Information

Begin Time	End Time	Total Person Minutes of Search	Camera and Photo Number(s)/Description(s)

Site Dry: Y N	Site Origin: Glacial Beaver Water Depressional Manmade Other________	Support Reproduction? Y N	GIS Mapping 0 1 2 3 4 5 6 7

Habitat Type:	Lake/ Pond	Wetland/ Marsh	Bog/ Fen	Backwater/ Oxbow	Spring/ Seep	Active Beaver Pond	Inactive Beaver Pond	Site Multipooled	Ditch/ Puddle	Reservoir/ Stockpond	Well/ Tank

Weather: Clear Partly Cloudy Overcast Rain Snow	Wind: Calm Light Strong	Air Temp °C	Water Temp °C	Water pH

Color: Clear Stained	Turbidity: Clear Cloudy	Water Connectedness: Permanent Temporary Isolated	Water Permanence: Permanent Temporary	Max Depth: < 1 M 1-2 M >2 M	Percent of Site > 2 M 0 1-25 26-50 51-75 76-100

Site Length:	Site Width:	Percentage of Site Searched: 1-25 26-50 51-75 76-100	Percent of Site at $\leq$ 50 cm Depth: 0 1-25 26-50 51-75 76-100	~ Emergent Veg Area (M^2)

Percent of Site with Emergent Veg: 0 1-25 26-50 51-75 76-100	Percent of Site with Larval Activity: 0 1-25 26-50 51-75 76-100	Rank Emergent Vegetation Species in Order of Abundance: ___Sedges___Grasses__Cattails___Rushes___Water Lily___Shrubs___Other

Primary Substrate of Shallows: Silt/Mud Sand Gravel Cobble Boulder/Bedrock	North Shoreline Characteristics: Shallows Present: Y N Emergent Veg Present: Y N	Distance (M) to Forest Edge:

Grazing Impact None Light Heavy Structure Heavy Structure and Water Heavy Water	Water Dammed/Diverted Y N	Timber Harvest in Area Y N	Mining Activity Y N

Other Human Impacts Or Modifications:	Fish Detected? Y N	Time at First Detection:	Fish Species If Identified:

Fish Spawning Habitat Present? Y N U	Inlet Width:	Inlet Depth:	Inlet Substrate	Outlet Width	Outlet Depth	Outlet Substrate

Species Information

Amphibian Species		Time at first detection	E L M J A	No. Egg Masses		5-20mm larvae	≤10 ≤100 ≤1000 ≤10K >10K
20-50mm larvae	≤10 ≤100 ≤1000 ≤10K >10K	>50mm larvae	≤10 ≤100 ≤1000 ≤10K >10K	Number Juveniles		Number Adults	
Tissue Number		Voucher Number		Breeding with Fish?	Y N	If breeding with fish is cover present?	Y N
Amphibian Species		Time at first detection	E L M J A	No. Egg Masses		5-20mm larvae	≤10 ≤100 ≤1000 ≤10K >10K
20-50mm larvae	≤10 ≤100 ≤1000 ≤10K >10K	>50mm larvae	≤10 ≤100 ≤1000 ≤10K >10K	Number Juveniles		Number Adults	
Tissue Number		Voucher Number		Breeding with Fish?	Y N	If breeding with fish is cover present?	Y N
Amphibian Species		Time at first detection	E L M J A	No. Egg Masses		5-20mm larvae	≤10 ≤100 ≤1000 ≤10K >10K
20-50mm larvae	≤10 ≤100 ≤1000 ≤10K >10K	>50mm larvae	≤10 ≤100 ≤1000 ≤10K >10K	Number Juveniles		Number Adults	
Tissue Number		Voucher Number		Breeding with Fish?	Y N	If breeding with fish is cover present?	Y N
Amphibian Species		Time at first detection	E L M J A	No. Egg Masses		5-20mm larvae	≤10 ≤100 ≤1000 ≤10K >10K
20-50mm larvae	≤10 ≤100 ≤1000 ≤10K >10K	>50mm larvae	≤10 ≤100 ≤1000 ≤10K >10K	Number Juveniles		Number Adults	
Tissue Number		Voucher Number		Breeding with Fish?	Y N	If breeding with fish is cover present?	Y N

Reptile Species		Time at first detection	E J A	Number Individuals		SVL in CM		Tissue Number		Voucher Number	
Reptile Species		Time at first detection	E J A	Number Individuals		SVL in CM		Tissue Number		Voucher Number	
Reptile Species		Time at first detection	E J A	Number Individuals		SVL in CM		Tissue Number		Voucher Number	
Reptile Species		Time at first detection	E J A	Number Individuals		SVL in CM		Tissue Number		Voucher Number	

Site Map For Lentic Breeding Amphibian and Aquatic Reptile Surveys

Grid Scale:

N↑

***** Indicate the following locations on the map: **T** = temperature, **G** = GPS reading, **C** = clinometer reading, and **P→** = photo locations and directions of photos. Indicate area with emergent vegetation with cross-hatching and indicate a 2-meter depth contour with a dashed line.

Other Notes:

Compass Bearing	70°	90°	110°	130°	150°	170°	190°	210°
Inclination (degrees)								

Definitions of Variables on Lentic Breeding Amphibian Survey Data Sheet

Locality Information

Date: Use MM-DD-YY format (e.g. 5/12/00 for May 12 of 2000).
Observers: List names or initials of individuals involved with survey of this site and circle the name of the recorder.
Owner: Use abbreviation of the government agency responsible for managing the land you surveyed. (e.g. USFS, BLM). If private land was surveyed list the owner's full name to indicate that you did not trespass.
Site Detection: Was site detected on aerial photo, topographic map, NWI map, or was it observed incidentally while in the field.
GPS EPE: The estimated positional error reported by the GPS receiver in meters.
Strata Number: The sample strata in which the 6th level HUC watershed lies (one of nine defined in western Montana).
HUC Number: The sample number of the 6th level HUC in one of the nine sample strata defined for western Montana.
Site Number: The number pre-assigned to the water body within each 6th level HUC. If the water body was not pre-assigned a number because it was not on topographic maps or aerial photos then assign it a sequential number and draw it on the topo map.
State: Use the two-letter abbreviation.
County: Use the full county name.
Map Name: List the name of the USGS 7.5-minute (1:24,000 scale) topographic quadrangle map.
Locality: Describe the specific geographic location of the site so that the type of site is described and the straight-line air distance from one or more permanent features on a 7.5-minute (1:24,000 scale) topographic map records the position of the site (e.g., Beaver pond, 1.5 miles south of Elephant Peak and 1.3 miles east of Engle Peak).
T: Record the Township number and whether it is north or south.
R: Record the Range number and whether it is east or west.
S: Record the Section number.
Section Description: Describe the location of the site at the ¼ of ¼ section level (e.g., SENE indicates SE corner of NE corner).
Map Elevation: The elevation of the site as indicated by the topographic map in feet (avoid using elevations from a GPS)
UTM Zone: Universal Transverse Mercator zone recorded on the topographic map. Use NAD 27 as the map and GPS datum.
UTM East: Universal Transverse Mercator easting coordinate in meters as recorded on the topographic map or GPS receiver. Be sure to note any major differences between UTM coordinates on the map and those on the GPS receiver.
UTM North: Universal Transverse Mercator northing coordinate in meters as recorded on the topographic map or GPS receiver. Be sure to note any major differences between UTM coordinates on the map and those on the GPS receiver.
Survey Type: Circle the appropriate number defined as follows: 0 = private land so site was not surveyed; 1 = site not surveyed due to logistics; 2 = site is a lotic spring/seep not worth future survey; 3 = lentic site that is worth future survey; 4 = misidentified as a potential lentic site on the aerial photograph or on the topographic map (e.g., a shadow from a tree or a talus slope) and not worth future survey; 5 = inactive beaver dam that now only has lotic habitat and is not worth future survey; 6 = only lotic habitat is present and the site is not worth future survey, but it appears possible that the meadow was an historic beaver dam complex; 7 = a lentic site because it would hold water for at least a short time period during wetter conditions, but it is not worth future survey because it would never hold enough water long enough to support amphibian reproduction; 8 = site is not worth future survey for some reason other than those listed above.

Habitat Information

Begin Time: List the time the survey began in 24-hour format.
End Time: List the time the survey ended in 24-hour format.
Total Person Minutes of Search: Record the total person minutes the site was searched (e.g. if one person surveys for 15 minutes and another surveys for 30 minutes, but takes 5 minutes to measure a specimen the total person minutes is 40 minutes).
Camera and Photo Number(s) / Description (s): Identify the camera and the number of the photo as viewed on the camera's view screen and a description of the contents of the photograph (e.g., 13 = 1 x ASMO larvae and 14 = 1 x habitat). Take photos of all portions of the site and anything else that may be of interest (e.g., areas with fish versus areas with amphibians).
Site Dry: Circle whether the site was dry or not at the time of the survey.
Site Origin: Circle whether the site origin is glacial, beaver, water (i.e., flooding or spring), depressional, manmade, or describe other origin.
Support Reproduction: Is site capable of supporting reproduction so it is worth resurveying (e.g. in wetter years if now dry)?
GIS Mapping: Circle the appropriate number defined as follows: 0 = site not surveyed; 1 = a 4 in the survey type and site is not worth future survey; 2 = a 2, 5, 6, or 8 in survey type and site is not worth future survey; 3 = 7 in survey type and site is not worth future survey; 4 = a 3 in the survey type and site is dry, but is worth future survey; 5 = a 3 in the survey type and site has ephemeral water and is worth future survey; 6 = a 3 in the survey type, site is worth future survey, has emergent vegetation, and has permanent water that lasts all summer long and does not freeze solid in the winter so that it is likely to support aquatic overwintering; 7 = a 3 in the survey type, site is worth future survey, does not have functional amounts of emergent vegetation, and has permanent water that lasts all summer long and does not freeze solid in the winter so that it is likely to support aquatic overwintering.
Habitat Type: Circle the appropriate habitat type of the site being surveyed. If site is multi-pooled water information does not need to be gathered for every pool, but you may wish to record this information on the map. If breeding activity is limited to one pool at a multi-pooled site water information should be recorded for this pool and this should be noted in the comments.
Weather: Circle weather condition during survey.
Wind: Circle wind condition during survey (> 20 mph winds should be classified as strong).
Air Temp: Record air temperature at chest height in the shade. Record temperature in Celsius. °C = (°F – 32)/1.8
Water Temp: Record water temperature where larvae or egg masses are observed or at 2cm depth 1 meter from the margin of the water body. Record temperature in Celsius. °C = (°F – 32)/1.8
Water pH: Record water pH at the same location water temperature was recorded.
Color: Circle whether the water is clear or stained a tea or rust color from organic acids.

Turbidity: Circle whether water is clear or cloudy.
Water Connectedness: Circle if water body has permanent connection to flowing water (Permanent), is connected to flowing water for a temporary period each year (Temporary), or is never connected to flowing waters or other water bodies (Isolated).
Water Permanence: Circle whether the site contains water throughout the entire year (Permanent), or contains water for only a portion of the year (Temporary).
Max Depth: Circle the category corresponding to the maximum depth of the water body.
Percent of Site > 2 M: Circle the percentage of the site with water depth greater than 2 meters deep.
Site Length: The length of the longest dimension of the standing water body.
Site Width: The width of the second longest dimension of the standing water body.
Percentage of Site Searched: Circle the percentage of the site surveyed.
Percentage of the Site at ≤ 50 cm Depth: Circle the appropriate percentage.
Approximate Area with Emergent Veg (M^2): The approximate area of the site that contains emergent vegetation.
Percentage of Site with Emergent Veg: Circle the percentage of the entire site with emergent vegetation.
Percentage of Site with Larval Activity: Circle the percentage of the site where amphibian larvae were observed.
Rank Emergent Veg Species in Order of Abundance: Record the rank order of abundance in front of the 3 most prevalent emergent vegetation species. If the vegetation present is "other" indicate what it is.
Primary Substrate: Circle the substrate that covers the majority of the bottom of the site.
North Shoreline Characteristics: Circle whether shallows and emergent vegetation are present or absent on the north shoreline.
Distance (M) to Forest Edge: Record the closest distance between the water's edge and the forest margin in meters.
Grazing Impact: Circle the appropriate grazing category defined as follows: no grazing noted in the vicinity of the site; grazing noted in the vicinity of the site, but no major impacts to wetland structure or water quality; heavy structural impacts to site (e.g.,vegetation destroyed creating bare ground, hummocks, pugging, or altered hydroregime); heavy structural impacts and water quality impacted due to animal waste; and water quality impacted due to animal waste.
Water Dammed/Diverted: Circle whether or not water has been dammed or diverted at the site.
Timber Harvest: Circle whether or not timber has been harvested in the vicinity of the site.
Mining Activity: Circle whether or not there is evidence of mining activity in the vicinity of the site.
Other Human Impacts or Modifications: Briefly describe if, how, and when the site has been altered by human activities. If the site has not been altered record none for not altered. If multiple anthropogenic impacts exist document all of these using the back of the data sheet if necessary and qualify approximate timing of impact (e.g., recent versus historic).
Fish Detected?: Circle whether or not fish were detected.
Time at First Detection: If fish were detected, indicate the time in total person minutes of survey when they were first detected.
Fish Species if Identified: List the fish species identified.
Fish Spawning Habitat Present?: Are shallow waters with adequate gravels/cobbles present that would allow fish to spawn? An active search for fry is also a good idea.
Inlet Width: What is the average width of the inlet stream in meters?
Inlet Depth: What is the average depth of the inlet stream in centimeters?
Inlet Substrate: What is the primary substrate at the inlet stream (Silt/Mud, Sand, Gravel, Cobble, or Boulder/Bedrock)?
Outlet Width: What is the average width of the outlet stream in meters?
Outlet Depth: What is the average depth of the outlet stream in centimeters?
Outlet Substrate: What is the primary substrate at the outlet stream (Silt/Mud, Sand, Gravel, Cobble, or Boulder/Bedrock)?

Species Information

For each species record the first two letters of the scientific genus and species names for all amphibian and reptile species found at the site (e.g., BUBO for *Bufo boreas*). Record the total number of person minutes of survey required before each life history stage of each species was encountered beside the E (egg), L (larvae), M (metamorph), J (juvenile), or A (adult). Record the number or category of number of each of the specified life history and/or size classes. For amphibians indicate whether they have bred in the same water body where fish are present, and if they have, indicate whether there is protective cover (e.g., extensive shallows with emergent vegetation, a log barrier, talus). Record the tissue number or range of tissue numbers for tissue samples collected (see tissue collection protocols). If the animal was swabbed in preparation for testing the animal for chytrid infection indicate the chytrid sample number in the Tissue Number field. Record the preliminary museum voucher specimen number for voucher specimens collected (see voucher specimen collection protocols).

Site Map for Lentic Breeding Amphibian and Aquatic Reptile Surveys

General: Include a rough sketch of the site including the shape of the site and the shape and spatial relations of surrounding biotic and abiotic features. Indicate the area covered with emergent vegetation with cross-hatching. Indicate a 2-meter depth contour for the water body with a dashed line. Indicate the location where the water temperature was taken, the location where the GPS position was taken, the location where clinometer readings for southern exposure were taken, and the location of any photographs with an arrow indicating the direction in which the photo(s) were taken. Make sure that the orientation of the sketch (i.e. the north arrow) corresponds to the orientation of the site.
Grid Scale: Indicate the approximate scale of the grid lines relative to the site sketched in meters.
Other Notes: Include any other notes of interest in this space. Examples: (1) areas of highest larval density; (2) thoughts on why a species may not have been detected at a site; (3) problems associated with the survey of the site (e.g., dangerous boggy conditions); (4) If a site was dry would it support reproduction during wetter years.
Southern Exposure: From a site on along the northern shoreline that would most likely to be used as an oviposition or larval rearing area (e.g., shallow waters with emergent vegetation in the NW corner of the water body) record the degree inclination from your position to the skyline (e.g., mountain or solid tree line) at each of the eight compass bearings listed. Note that the compass bearings are true north so you will need to adjust your compass according to the map being used to correct for the deviation from magnetic north (15 to 19.5 degrees in western Montana).

Appendix B

Watershed Summarization Data Sheet for Amphibian and Aquatic Reptile Inventory

Strata Number:	**HUC Number:**	**Drainage Name:**	**Crew Leader:**	**Survey Dates:** (Enter Range)	**Quad Map Names**

No. Potential Lentic Sites In HUC:	**No. Potential Lentic Sites Surveyed:**	**Number of Incidental Lentic Sites:**	**No. Wet Lentic Sites That Could Support Reproduction:**	**No. Dry Lentic Sites:**	**Potential Lentic Sites Not Surveyed:**

Lentic Sites Found Incidentally:	**Dry Lentic Sites:** (Underline if reproduction may be supported in wetter year)	**Wet Sites (lentic or lotic) Where No Species Were Detected:**

No. Active Beaver Sites:	**No. Inactive Beaver Sites with Lentic Breeding Habitat:**	**No. Inactive Beaver Sites Without Lentic Breeding Habitat** (include sites that seem likely to have originated by beaver, but list site numbers for those for which there is uncertainty)

Sites with Potential for Aquatic Overwintering:	**Other Potential Aquatic Overwintering Sites (e.g., permanent streams from a specified tributary mouth or map section)**

Permanent Lentic Sites with Emergent Vegetation: 002, 006, 007, 009	**Permanent Lentic Sites without Emergent Vegetation:** None

Species	**Sites Where Species Was Detected** * Underline those with Reproduction * Include numbers of BUBO adults, larvae, and metamorphs and any comments	**No. Potential Sites Detected**	**No. Wet Lentic Sites Detected**	**No. Wet Lentic Sites with Reproduction**	**No. Incidental Observations**	**Voucher Numbers**	**Tissue Sample Numbers**

Comments: (e.g., discuss why any sites were not surveyed, whether "dry" sites are worth reexamining in wetter years, and any other general comments you might have about the watershed (e.g., mining, timber harvest, or grazing impacts, beaver activity, need to resurvey the watershed due to drought or timing of survey, or need to survey adjacent private lands)):